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A SKETCH OF THE HISTORY OF PSYCHOLOGY AMONG THE GREEKS.

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The following paper is an abstract of six lectures delivered at Clark University in the autumn of 1890 on the history of psychology among the Greeks from the earliest times down to Aristotle.[1] The psychologists of this period are the philosophers, and their psychological doctrines are for the most part so intimately bound up with their philosophy that a sketch of the former necessarily involves some mention of the latter. We must therefore devote a few words to the metaphysics of each philosopher before taking up his psychology. But the psychological theories of the Greek philosophers stand in the closest relation to the animistic beliefs that prevailed among the early Greeks; and our sketch would be unintelligible without a preliminary account of these.

I.

Long before scientific psychology begins, there exists an ancient popular psychology, which embodies the earliest naïve notions of uncivilized men about the soul and its activities. These notions are found among barbarous and semi-

[1] The chief authorities on the psychology of the Greeks are the great work of Zeller, Die Philosophie der Griechen, of which I have used the last edition; and Prof. Siebeck's Geschichte der Psychologie, Gotha, 1880-84, which is completed as far as Thomas Aquinas. On the animistic conceptions of the Homeric Greeks, see Erwin Rohde, Psyche: Seelencult und Unsterblichkeitsglaube der Griechen, Freiburg i. B., 1890, pp. 1-11. On the relation between Greek psychology and animism, see Julius Lippert, Die Religionen der europäischen Kulturvölker, Berlin, 1881, Einleitung and pp. 250-275.

barbarous tribes in all parts of the world. Their universal diffusion is better authenticated than that of religion itself. Linguistic research proves that they were entertained by our Aryan ancestors; and the Homeric poems furnish the amplest evidence that they were shared by the early Greeks.

The animistic notion of the soul, according to Tylor,[1] is that of a "thin, unsubstantial human image, in its nature a sort of vapor, film, or shadow; the cause of life and thought in the individual it animates; . . . capable of leaving the body far behind, to flash swiftly from place to place; mostly impalpable and invisible, yet appearing to men waking or asleep as a phantasm . . . . ; continuing to exist and to appear to men after the death of the body . . . . . . " The soul is thus that whose indwelling in a man causes him to be alive, and whose departure causes him to die. Its existence is assumed in the first instance for the purpose of explaining the difference between life and death. The movement and activity of living beings must, it is felt, be due to some interior cause, and this cause is called the soul. The abrupt transition from life to the stillness of death is explained as due to the departure of the soul.

That this is the true origin of the notion of the soul, we have evidence in certain further beliefs that are well-nigh universal among uncivilized peoples. In the first place, the soul is represented as analogous to, if not identical with, the breath: hence the Hebrew words *nephesh*, *ruach*; the Greek *psyche*, from *psychein* to freshen with the breath, and *pneuma*, from *pnein* to blow; the Latin *anima*, *animus*, connected with the Greek *anemos*, wind, and *spiritus*, from *spirare* to breathe. Now the commonest observations of the difference between life and death would naturally lead men to connect the soul both with the breath and with the blood. For, in the first place, loss of blood means loss of vital force, and if too much blood be lost death is the consequence. In the second place, men breathe as long as they are alive, and cease to breathe when they die. Furthermore, the savage has no clear conception of the function of the lungs, but supposes that in some way the inspired air gets into the blood and is carried by it all over the body. It is thus a pretty consistent theory which identifies the soul with the breath, and finds its special seat in the blood.

Such, then, were the conceptions of the Homeric Greeks regarding the soul and its relations to the body. In what sense they conceive the soul to be the cause of life and movement appears from their views of its condition after death.

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[1] Primitive Culture, I., p. 429.

When death overtakes a Homeric warrior, his soul escapes through his mouth, or through a gaping wound, and hurries to the house of Hades. When separated from the body it is called *eidolon* or image. These images are thin and unsubstantial as smoke or shadow; being "as the air invulnerable," they elude the grasp of the living. Their life in the lower world is a pale, disconsolate one; indeed, they can hardly be said to live at all, for they no longer possess consciousness and volition; the truth is that "they do not live, but only exist." There is, however, one means by which they can temporarily recover life and consciousness, and that is by partaking of blood. The soul cannot therefore, in the conception of the Homeric Greeks, be said to be the independent possessor of life and consciousness. Only so long as the soul remains connected with the body — only so long as the soul retains its union with the blood — does mental activity continue. It follows that sensation, thought, and volition are functions of the living being which soul and body constitute, not of the soul alone.

While the blood in general is conceived to be the seat of the soul, the mental faculties are assigned a special seat in the breast. Thus the word for midriff or diaphragm is the common expression for mind; for the main reservoir of the blood is in the breast, and the midriff is put by metonymy for this entire region. Similarly, the various words for heart are used to denote the subject of the states of feeling. In general, the attention of the Homeric Greek is turned more especially towards the robuster states of feeling; which explains why the psychical activities, including even perception and thought, are supposed to have their seat in the breast, and not at all in the head or the brain.

II.

Down to the time of the Sophists, the Greek philosophers are mainly occupied with cosmological problems. When the Ionics declare that all things consist of water, air, or fire, they do not mean by water, air, and fire just what we mean by these words. The conception of matter as matter, that is, as lifeless, passive, inert substance, is a late scientific product. Nor must we imagine that the problem they are endeavoring to solve is a purely physical and not rather a biological one. They are not leaving living beings out of account, and seeking simply to explain the mutations of matter; on the contrary, they regard all matter as alive, and if they select water, or air, or fire, as their fundamental principle, it is because they think they see in this form of matter rather than in any other the essential basis of life.

The early Greeks, as we have seen, consider the soul to be closely connected with the breath, and to have its seat in the blood. Now there is a difference between living and dead blood; when the blood of a dying man flows out into the air, it grows cold, coagulates, and dries. Thus, at the same time that the soul disappears, the warmth and moisture of the blood disappear. It is furthermore a striking fact that the breath also is both warm and moist, and that it leaves a palpable residuum of warm moisture behind it. What more natural, then, than to take this warm moisture which is the common element in both blood and breath, and identify it with the soul?

This is what *Thales* does when he declares that the first principle of things is water. Water, he says, is the substance of which all things consist. In men and animals, it is the warm moisture of the blood upon which life and movement depend. Since this is so, the life and movement of external nature are to be accounted for by the same analogy; they must be due to the fact that all things are at bottom forms of water. Hence his statements that "the whole world is alive and full of gods," that is, of souls; and that even the magnet has a soul, since it is able to produce motion.

Aristotle conjectures that Thales may have been led to his theory by the observation that the food of all animals is moist, and that they all originate from moist seed. However this may be, we know that *Hippo*, a contemporary of Thales, who agreed with him in identifying the soul with water, or rather with moisture, strongly combatted the traditional view that the soul is in the blood, and maintained that it is in the seed. He seems to have supposed that the seed is not only the starting-point from which the new individual is developed, but remains in the body throughout life and forms the nucleus in which the vital activities centre. We thus have two opposite theories of psychogenesis—the one that the soul is in the blood, and is therefore derived from the mother; the other that it is in the seed, and therefore derived from the father.

Anaximenes regarded air as the stuff of which the soul consists, and held that all things are formed out of air by condensation and rarefaction. This theory is little more than a philosophical re-editing of the popular view that in breathing the soul is nourished by the inspired air, which, it is argued, must therefore be of the same nature as the soul.

Diogenes of Apollonia agrees with Anaximenes in identifying the soul with air. The centre of life and thought is the heart; here the blood is formed, and here it is mingled with air, which it carries to every part of the body. "The life

which pervades the entire body has its source in the blood, which is foamy and filled with air." He also points out that the seed is foamy and filled with air, "like the blood"; and does not forget to insist that in both cases an essential quality of this air is its warmth.

It is only an accentuation of this view when *Heraclitus*, the greatest of the Ionic philosophers, maintains that all things consist of fire. By fire he does not mean flame, but a dry warm vapor, which he conceives to be the essence of fire. Fire, in this sense, is the stuff of which the soul consists, and is present in the breath as its essential constituent. Heraclitus has by no means abandoned the popular notion which finds the principle of life in the blood and the breath; it is only a different constituent of these which strikes him as essential, namely the quality of warmth. On the one hand, he is deeply impressed with the phenomenon of animal heat; on the other, the observation of the subtle, penetrating, mobile, destructive character of fire outside the organism convinces him that this, of all other natural substances, is the principle of life and activity. All things consist of fire, but not all things manifest the familiar qualities of fire. For all things are in eternal flux; all things are continually changing their qualities. This happens because all things are continually undergoing either condensation or rarefaction. In their state of highest rarefaction they are what we call fire, and then it is that they manifest the qualities of soul; but the process of condensation now transforms them successively into air, water, and earth. The human organism is compounded out of the elements at the bottom and those at the top of the world-process, in such a way that the body consists of earth and the soul of fire. The mechanical bond which connects the individual soul with the diffused soul of the world is respiration; in respiration we breathe in the fire and therefore the rationality diffused in the air.

Empedocles conceives all natural objects to be mixtures of four original elements — fire, air, water, and earth — which he was perhaps the first thus to distinguish; and to be subject to the action of two forces, one attractive and the other repulsive, to which he gives the allegorical designations of love and hate. In the course of his physical theory he seems to have made no mention of the soul, and nowhere to have dropped a hint that he regards it as a being distinct from the body. But he mentions various psychical activities, and his explanation of them is a consequence of his philosophical theory. The faculty of thought, for example, he explains as consisting in a certain mixture of the substances that compose the blood, and he explains the other faculties in a similar manner.

We find an analogous view in the *Pythagorean school*, certain members of which held that the body consists of two pairs of opposites, the warm and the cold, the dry and the moist, and that the soul is the harmony or appropriate mixture of these. Besides this the Pythagoreans put forth two further views of the nature of the soul. The first is a deduction from their philosophy, whose fundamental thesis is that the essence of the world consists in numbers, or the mathematical properties of things; in conformity with this principle they define the soul as a number endowed with the power of self-movement. The other view is of a religious nature, and closely allied to the tradition propagated in the Orphic mysteries; it regards the soul as an immortal being, imprisoned in the body as a punishment for its sins, and calls the body the tomb of the soul. This view was subsequently taken up by Plato, and gives a characteristic coloring to his whole psychological theory.

III.

To understand the philosophical basis of the psychology of *Democritus*, we must go back to the Eleatics, whose fundamental principle is the exact opposite of that of Heraclitus. Heraclitus is so impressed with the fact of change that he makes it the principle of things; for his fire is simply the personification of restless change. Parmenides, on the other hand, thinks he sees clearly the impossibility of such a thing as change; that one thing should change into another different from itself seems to him to involve a contradiction. He therefore denies the reality of the sensible world, where such changes seem to occur, and affirms that the only reality is all-inclusive "Being," and that "Being" remains forever immutably what it is. The atoms of Democritus are simply the "Being" of Parmenides cut up very fine. Like it, they are ingenerable, indestructible, and immutable. They possess only mathematical qualities, and therefore differ from one another only in shape, order, and position. They are infinite in number, and together constitute the universe, and there is nothing beside them.

Though the soul is distinct from the body, it is impossible on atomistic principles that it should be other than corporeal. But the matter of which it consists must be of a sort to explain its essential properties, which are, first, motion, and secondly, thought. Now motion can only proceed from that which is itself in motion, and the soul must therefore consist of the most mobile kind of atoms; these are the very fine, smooth, round ones that constitute fire. Democritus thus agrees

with Heraclitus that the soul is of the nature of fire. This harmonizes well with the second essential property of the soul, thought; for thought is itself a subtle kind of motion. The fiery atoms that constitute soul are diffused through the entire body, in such a way that between every two body-atoms there is a soul-atom. The body is alive in all its parts, because in all parts there are atoms which by virtue of their nature are in continual motion, and which therefore set in motion the atoms that surround them. But the motion of the soul-atoms is not the same in every part of the body; that is to say, the different psychical activities have their seat in different parts, thought in the brain, anger in the heart, desire in the liver. Since the fiery atoms that constitute soul are everywhere diffused in space, the whole world must be alive; yet not in the sense of a unitary being. "There must be much soul diffused in the air, how otherwise could we breathe in life and soul out of it?" The preservation of life depends upon the uninterrupted accession of new soul-atoms from without in breathing. For since the soul is not completely enclosed by the body, some of its atoms are continually escaping; the surrounding air presses them out of the body because of their smallness and fineness. Breathing not only introduces new soul-atoms into the body, to replace those that are lost, but mechanically obstructs the exit of those that remain. When breathing ceases, the last obstacle to the escape of the soul-atoms is removed, and their departure is what we call death.

The fact that this theory is materialistic does not prevent it from being an almost perfect reproduction of primitive animism; for animism itself is vaguely materialistic. The theory of atoms is the only novel feature. We may point to the following elements as distinctly animistic: the view that the soul is not immaterial, but only a more ethereal kind of matter than the body; the view that in breathing the soul receives nourishment from without; the view that the soul lives in the body while breathing continues, and disappears with the breath; the view that the soul is identical with the bodily warmth.

In the theories we have thus far considered, the common tendency has been to regard the soul as a refined form of matter. We cannot say that *Anaxagoras* gets wholly beyond this view, for he says that mind is unlimited, that it is the finest and purest of all things, and that in different objects there are greater or smaller portions of it. Nevertheless, if he still conceives mind as a form of matter, he manifests a clear insight into the radical difference that separates this form of matter from every other form. It is interesting to observe

the characters by which he seeks to differentiate mind-stuff from ordinary matter. Ordinary matter is a mixture of all things, containing particles of flesh, blood, vegetable tissue, gold, silver, etc., indiscriminately mingled together. In fact, every object contains particles of all existing substances, and receives its name as this or that only from those that predominate. "All things are together, everything is in everything else." In contrast to the indiscriminate mixedness and mutual dependence of ordinary matter, there must have existed from the beginning a special kind whose privilege it was to be absolutely independent and unmixed; for only that which is unmixed can have power over and know that which is mixed. This is what Anaxagoras calls *nous* or mind. Since mind has no constituents, it can have no qualities or differences within itself, but must be homogeneous throughout; while ordinary material things differ from one another according to their composition. Only by having no qualities can it *move* other things; for if it had qualities, it would be one among things, and they would then act upon it, and its dominion over them would not be absolute. Only by having no qualities can it *know* other things; for if it had qualities itself, these would dim its vision and prevent it from perceiving clearly the qualities of things. Mind is thus altogether active in its nature, and alone able to act without being acted upon. When it acts upon matter, it causes motion; in fact, mind is the original source of all motion. We might suppose motion to be uncaused and to be equally original with matter, were it not for the order and beauty which pervade the world, and which come about by means of motion; but these show that motion must have proceeded from some spiritual source, that is, from mind. Mind is thus the ruling element in the world, it "knows all things and has the greatest power."

It will be evident that the psychology of Anaxagoras marks the widest departure from animism we have yet encountered.

IV.

It does not enter into the plan of this sketch to present in detail the views of the pre-Socratic philosophers regarding the physiology and psychology of the senses; but we may insert at this point an account of the most ingenious and suggestive of these theories, that of Democritus, which will serve as a specimen of their general character.

In order that sensations may take place, it is necessary, according to Democritus, that portions of the external object should come in contact with the sense-organs, and that the impression there produced should be propagated into the in-

terior of the body and communicated to the atoms of soul. The impression on the sense-organ must have a certain intensity, that is to say, the parts that touch the sense-organ must have a certain density and solidity, otherwise no sensation arises; tones, for example, find access to the soul through every part of the body, but are heard only through the ears, because it is only through these that they find access in sufficient quantity. Democritus regards the sense-organs as merely passage-ways for matter; thus the essential feature of the eye is its moist and spongy character, and the ear is only a tube which admits the vibrating air into the body.

Visible objects give off effluences, which are images or copies of themselves in miniature, as it were their peeled-off surfaces. These images are complexes of atoms, like the objects from which they come. The essential thing in vision is, first, that these images should be reflected in the eye, and secondly, that the impressions thus produced should be propagated as far as the atoms of soul. Strictly speaking, it is not the images that leave visible objects that are reflected in the eye; for the space between objects and our eyes is filled with air, and the air is densified by the warmth of the sun, and this obstructs the passage of the images themselves; so that what actually reaches the eye and is reflected there is the likeness of the images impressed upon the densified air. This is why we see indistinctly at a distance; if the space between objects and our eyes were empty, we should be able to see an ant in the sky. A second hindrance to vision is the fact that effluences are continually given off by our eyes. It follows that we do not perceive things just as they are, but that the qualities of visible objects are partly subjective. Color is a purely subjective phenomenon, the objective cause of which lies in the mathematical qualities of things, which are the only qualities they possess in themselves. Here we have the earliest statement of the distinction between the primary and secondary qualities of matter. There are four fundamental colors — white, black, red, and green — all others are mixtures of these.

Passing to the sense of hearing, a sound or a tone is defined as a stream of atoms proceeding from a sonorous body. This stream sets in motion the air that lies before it, and thus produces a current consisting partly of atoms from the sonorous body, partly of atoms of air. In this current the atoms that have the same size, smoothness, roundness, and fineness drift together. The stream enters the body through the external passage of the ear and penetrates as far as the atoms of soul; when it acts upon these, auditory sen-

sations arise. A tone is purer in proportion to the homogeneousness of the atoms that compose the stream, higher in pitch in proportion to their smallness and fineness.

When certain of the effluences of things are inhaled into the nostrils, we have sensations of smell. A sweet taste is due to large, round atoms, which penetrate through the entire organism and affect it everywhere mildly and pleasantly. A sour taste is caused by rough, angular atoms; the taste of fat by small, thin, round ones. The atoms of a white object are "like the inner surface of a shell," that is, they are well-rounded, and they cast no shadows; those of a black object, on the contrary, are rough and uneven, and cast shadows. Objects that are smooth to the touch have their atoms regularly arranged; rough objects have their atoms irregularly arranged. The subjective qualities that objects present are due not only to the character of their atoms, but also to the quickness or slowness with which the effluences move, and the momentary density of the air through which they move.

Before passing to the psychology of Plato and Aristotle, we may devote a few words to the epistemological views of the pre-Socratic philosophers, which throw an instructive light upon their psychological method.

Heraclitus, Empedocles, and Democritus agree in subscribing to the theorem that like is known by like. Heraclitus states generally that we know the external fire by means of the fire within us. Empedocles goes further, and holds that our bodies contain water, earth and air as well as fire, and that we know air by means of the air in us, water by means of the water, and earth by means of the earth; in short, his assumption is that, if the external world is to be known, its constituents must also be those of the knowing subject. This theory may have found confirmation to his mind in the observation that the individual senses resemble the objects they are fitted to perceive: thus the eye not only perceives shining objects but shines itself, the air in the hollow of the ear resembles the external air, the skin is solid and resisting like the objects it touches, etc. Empedocles further states that the blood is adapted to be the substratum of thought because it contains all the elements mixed together, and that this is especially true of the blood in the neighborhood of the heart. Democritus adopts the same view when he says that we perceive everything with that part of our nature which is allied to it, and that the closer the resemblance between the two the more exact the sensation. He draws from this view a couple of sagacious inferences: that there are probably many things which we do not perceive because they are not suited to our senses; and that other beings may have senses which we do not possess.

Anaxagoras, on the other hand, is obliged, in consistency with his fundamental principle, to break with the theory that like is known by like ; for mind is altogether unlike the material things it knows. Now one thing acts upon another by changing it into its own likeness; like therefore makes no impression upon like, for it produces no change in it ; only unlike can act upon unlike in such a way as to alter it. Knowledge therefore depends upon the percipient subject being unlike the perceived object. Anaxagoras thus appears to recognize that sensation is a qualitative change of the subject, which cannot be produced by that which resembles the latter. He has not far to seek for observations to bear out this view; for instance, temperature sensations depend upon the skin being either warmer or colder than the object. He applies the same analogy to vision: vision, he says, consists in a reflection of the object in the eye-ball, but the background upon which it is reflected must be of a different color from the object, and this is why we cannot see in the dark, for all objects are then of the same color as the interior of the eye.. Unlike, then, is always perceived by unlike. Since everything is in everything else, our bodies must contain particles of all possible substances; and this enables us to perceive every quality of external objects by means of its opposite in us — the rough by means of the smooth, the bitter by means of the sweet, etc.

Parmenides, Heraclitus, Empedocles, and Democritus all distinguish expressly between perception and thought, and give the preference to thought as the only trustworthy source of knowledge. Parmenides does so because the senses make it appear as if there were such a thing as change ; Heraclitus, because they make it appear as if there were such a thing as permanence. Even Democritus, in spite of the consistent materialism of his theory, is obliged to recognize the superiority of thought ; for the atoms of which all things are ultimately composed are imperceptible to sense, and must therefore be known by means of some higher faculty. Yet he says that the difference between perception and thought is only one of degree, the knowledge of the intellect being merely more acute than that of the senses ; for both consist solely in material changes, and are produced in the same manner, by means of mechanical impressions from without. Indeed, it is difficult to see from the account he gives how perception and thought are differentiated from each other. Yet Democritus thinks very differently of their worth ; sensible knowledge, he says, is "dark," the only genuine knowledge is that of the intellect.

V.

The distinctive position of *the Sophists* is that of scepticism in regard to the possibility of objective knowledge. Democritus had observed that colors, sounds, etc., are affections of the subject, not qualities belonging to material things in themselves. The Sophists generalize this observation, and maintain that all qualities and attributes without exception, in short the total content of knowledge, is merely a subjective state. This insight leaves it an open question whether the content of knowledge reproduces the actual relations of things. It is possible to doubt whether it does: and this doubt is Sophisticism.

One of the principal Sophists, *Protagoras*, bases his theory upon Heraclitus' doctrine of eternal flux. The universe, he says, consists of nothing but a vast multitude of colliding motions. Every sensation is the result of two such motions; a color-sensation, for instance, arises when a motion approaching the eye from without collides with the motion that constitutes the glance of the eye. And every other state of mind is produced in the same way — pleasure and pain, desire and fear, knowledge and thought. It follows that things exist only as they appear, and that as they appear to every man, so they are. That things exist apart from appearances, is an assertion that cannot be substantiated.

Plato relates in the Phaedo that *Socrates* had accepted as a youth the traditional notion of the soul, but had subsequently lost confidence in it. He would always ask "whether it is the blood by virtue of which we are rational, or air, or fire?" The explanations of the philosophers were so unsatisfactory, that he resolved to abandon psychological and cosmological investigation, believing it a waste of time, and ever after expressing contempt for a knowledge that had no bearing upon action. Socrates agrees with the Sophists in holding that knowledge is a state of the subject, but declines to draw the conclusion that universal and necessary knowledge is therefore impossible. He holds that side by side with our perceptions we have mental states of a different kind which enable us to distinguish between the true and the false — namely, concepts or class-ideas. The business of philosophy is the investigation of these and the determination of their proper content; and we read in Xenophon and Plato how Socrates would discuss the meaning of beautiful and ugly, just and unjust, pious and impious, the essence of prudence and folly, the nature of the family and of the state, etc. He believed that all men, when they think consistently, have identical concepts about such matters, and that therefore, however their perceptions

may differ, they have objective knowledge, at least in moral matters, by virtue of their concepts.

The philosophy of *Plato* is the first great systematic expression of that tendency of thought which places mind before matter as the first principle of things. Such a philosophy involves the consequence that the ultimate ground of all existing things must be sought in the domain of ethics; and so it comes about that the psychological views of Plato are largely influenced by ethical considerations.

The work of previous philosphers has left the postulate that the ultimate ground of existence must be unitary, in contrast to the multiplicity of phenomenal things, and constant, in contrast to their ceaseless flux. The concepts of Socrates seem to Plato to suggest a better hypothesis in regard to the ground of existence than any yet proposed. For the unity of the concept contrasts with the multiplicity of the individual objects to which it applies, and its fixity contrasts with their endless variability. Furthermore, concepts form an articulate system, the lower being included in the higher, and a highest concept including all the others. Now perception merely reveals to us the outward shows of things, while thought acquaints us with their inner reality. If then, every percept corresponds to some external reality, how much more must every concept have a reality corresponding to it? The realities that correspond to concepts are the Platonic Ideas, and the highest Idea, which includes all the others, is the Idea of the Good.

Our two faculties of perception and thought thus reveal to us two disparate worlds: perception reveals a world of individual objects, where all is multiplicity and change; whereas thought opens up to us a realm of supersensible essences, which together constitute a unitary spiritual being, the Idea of the Good. Since the relations of the Ideas correspond exactly to the relations of the concepts by which we know them, we can find out all about reality by turning our attention inward and investigating the mutual relations of our concepts. Here we have the great original of the *à priori* type of philosophy, which disdains experience and undertakes to discover truth by the effort of unaided thought.

It might be expected, since all souls form a class, that Plato would recognize an Idea of the soul. But since the contrast between the Ideas and their individual copies is that between the eternal and the transitory, this would be equivalent to denying the immortality of the soul, which his ethical interest forbids. He therefore assigns to the soul a middle position between Ideas and individual things. He says, moreover, that though there is no Idea of the soul, there is an Idea

with which it is indissolubly connected, namely the Idea of life; which is as much as to say that the soul is the principle of life. Plato believes that the world as a whole is animated by a soul. For the world is a copy of the Idea of the Good, and must therefore be as perfect as possible; now what has reason is more perfect than what has not, but only soul has reason: hence the visible world must have a soul. Hence, in the Timaeus, Plato calls the visible world "a blessed god."

Plato's statements regarding the nature of the soul are made in the first instance with reference to the world-soul. He says that the soul existed first, and the body was formed afterwards, thus recognizing the priority of the soul to the body. The soul is not a mere harmony of the body, as the Pythagoreans maintained; if it were, it would perish with the body. It *has* harmony, but that does not exhaust its being. It is a substance, diffused in harmonious proportions throughout the visible world. The essential qualities of this substance are simplicity, invisibility, and incorporeality. The activity of the soul is twofold, consisting partly in motion and partly in knowledge. The soul is the original source of motion, for it alone is self-moving; all other things receive their motion from without, but the soul moves itself, and in moving itself moves the body. The soul knows all things, for it has the most perfect kind of motion, the circular, by which it "returns into itself and informs itself of everything it has met in its course." All inferior beings have their soul by participation in the world-soul. The highest individual souls are those of the heavenly bodies, next come the souls of men. The end for which the human soul exists is the attainment of rational knowledge, for the soul is by nature "fond of learning." "As the eye is fitted to perceive the sunlight, so is the soul to contemplate the Idea of the Good." Now the contemplation of the Idea of the Good is possible only by rising above sense-experience, and sense-experience has its source in the body. The body is thus little more than a hindrance to the soul; it is a misfortune to the soul to be imprisoned in it; the body is the grave of the soul. The soul did not always dwell in the body, but descended into it from a former celestial state; in its proper nature it has no need of the body; it lives best and happiest when it pays as little attention to the body as possible. For the proper activity of the soul is thought, or the contemplation of ideas, and to this the body can be no help, but only a hindrance.

Since the soul existed before its union with the body in a better state, in which it was entirely occupied in pure thought,

it is evident that the sensible part of the soul does not belong to its real nature. Plato therefore divides the soul into two parts, one immortal, the other mortal; and the latter he subdivides into two, a nobler and an ignobler part. We thus have three parts of the soul:

1. A rational or immortal part, whose activity is thought.
2. A nobler mortal part, to which belong courage, anger, love of power, and in general the better and stronger states states of feeling.
3. An ignobler mortal part, to which belong pleasure and pain, and all the sensual appetites and passions.

In proof that these three are not merely distinct forms of activity, but separate parts, Plato instances the fact that desire is sometimes at strife with reason, and sometimes fights on its side: activities so independent of each other must spring from separate causes. How this trinity of parts is to be reconciled with the unity of the soul, Plato does not explain; they are in reality three connected beings, not one being. Each of the three parts has its special bodily seat. That of thought is the head, and the senses are the instruments it employs; that of courage is the breast, and particularly the heart; that of desire is the belly. The liver is the seat of imagination, by means of which reason rules desire; "upon its polished surface reason causes now terrifying, now diverting images to be reflected, she alters its natural sweetness and color by the introduction of bile, and so either frightens or soothes the appetitive part into obedience." But the soul is also mingled with the spinal marrow. That part of the marrow which is rounded into a ball and enclosed in the skull contains the divine part of the soul; the remainder of the marrow contains the mortal part. Both of these parts are ensheathed in a case of bone, the lower end of which is connected by a tube with the passage for drink, by which liquids pass through the lungs and into the bladder; through this tube the seed makes its escape, for the seed comes from the marrow and therefore contains soul.

The sense-physiology of Plato marks no advance beyond that of Democritus. He observes that as a rule only movable parts have sensation; those that cannot be voluntarily moved, as for example bones and hair, are insensitive. Sensation arises whenever an external impression communicates a motion to the body, and this motion is propagated as far as the soul. As to what conducts these motions, Plato thinks it is the blood in the blood-vessels, owing to its mobility; for both Plato and Aristotle are unacquainted with the nerves. If the motion of the blood takes place very gradually, no sensation is produced; if it takes place quickly, but easily and

without obstruction, we have clear perception, without pleasure or pain; but if it causes a sensible raising or lowering of the general state, in the one case pleasure arises, in the other pain. Sensations of smell arise when vapors penetrate into the blood-vessels between the head and the navel, and cause there either a rough or a gentle motion. Sensations of taste depend upon the contraction or dilatation of the blood-vessels of the tongue. Auditory sensations arise when external sounds set in motion the air in the interior of the ear. Visual sensations are produced when the fire emitted by the luminous body collides with the fire that dwells in the interior of the eye. Finally, Plato distinguishes from sense-perception the faculty of thought, by means of which we compare our sensations, recognize their relations to one another, and infer from them the existence of actual objects; but the highest exercise of thought is the contemplation of the divine Ideas.

VI.

Aristotle aims in his Metaphysics to explain the universe by indicating the principles that enter into its construction. He finds that these are four in number: first, the material cause, or stuff of which the universe is composed; secondly, the formal cause, or idea of which it is a realization; thirdly, the efficient cause, or motive force which brought it into being; and fourthly, the final cause, or end which its existence subserves. These four principles — matter, form, motive force, and end — must coöperate to produce the universe as a whole or any portion of it.

If we try to classify these principles with reference to the source from which they come, we have on the one side matter, which must in every case be furnished from without; and on the other side the ideal form, the efficient act, and the purpose or end, all of which have their origin in the mind. It thus happens that these last three tend to coalesce into a single principle called Form, which stands opposed to matter as that which originates in the mind to that which originates from without. Matter, though the raw material out of which all existing things are formed, is in itself formless and chaotic; it is likewise wholly passive and unable to move itself. Form, on the other hand, is the principle of activity and the original source of motion. It is that which, by supervening upon unformed matter, transforms it into a concrete object, and may therefore be said to be the ideal of the concrete object it subsequently becomes. In fact, it is Aristotle's substitute for the Platonic Idea, and is even occasionally called by the same name. But there is an important difference between the Platonic

Idea and the Aristotelian Form. Plato represented the Ideas as existing apart from concrete objects in a transcendental realm of their own; Aristotle maintains that they must be immanent in the objects themselves. Only individual things, according to Aristotle, are real in the proper sense of the term; Forms or Ideas, apart from the individual things in which they are realized, are mere figments of the imagination. As in Plato, the ideal or Idea of an individual object is identified with the generic in it, that is, with that assemblage of traits which makes it member of a class. But what is most foreign to our habits of thought is the assumption that the generic in an individual object is not a mere part of its description, but the active force that causes all the changes it undergoes. Change, on this view, consists not so much in Matter taking on new Forms, as in the Forms successsively taking possession of Matter. Matter already contains within itself potentially all the various things it is capable of becoming; when the Forms supervene upon it, this potentiality becomes an actuality. Change may therefore be conceived as the transformation of a potentiality into an actuality.

We are now in a position to understand Aristotle's definition of the soul and his view of the relation between it and the body. Plato may be said to have conceived the union of soul and body as the spatial juxtaposition, as it were, of two independent substances. Aristotle, on the other hand, regards man as an organic whole. He says that the nature of each part must contain the reason for its union with the other. Of this organic whole the soul is the more significant side, yet we cannot say that the soul is the true man and the body a mere appendage. The soul does not think, feel, learn, etc., but the man does so by means of his soul. Old age, illness, drunkenness, etc., are not states of the soul alone, nor of the body alone, but of the unitary being that soul and body constitute. The soul is primarily the cause of life. Now life consists essentially in the power of self-movement, in the capacity of a being to produce changes in itself spontaneously, whether these changes are of a gross character visible to the eye, as in locomotion, or are limited to the minute internal movements that constitute nutrition and growth. We thus have a body in which changes are produced, and an inner principle which produces them, and the relation of the two is exactly that between Matter and Form. Since the body cannot move or change itself, it must be of the nature of Matter; and the soul, as that which moves and produces changes in the body, must be of the nature of Form.

Since all matter is the potentiality of that which it can become, the body must be the potentiality of a living being;

and since the soul is that which transforms this potentiality into an actuality, the soul may be described as the *entelechy* or actuality of a living being. But the word *entelechy* is ambiguous, for it may mean either the actualizing agency, or the activity of actualization. The soul is an *entelechy* in the former sense, for it exists even during sleep, when its functions are suspended; the soul is thus the ever-present possibility of the functions of life. To indicate that the soul is an *entelechy* in the sense of an actualizing agency, Aristotle calls it the *first entelechy*, and his definition therefore reads: the soul is the first *entelechy* of a natural organic body that has in it the potentiality of life. Since the soul is the form of the body, it must be immaterial; but, though immaterial, it cannot exist apart from matter. Indeed, Aristotle mentions a special kind of matter with which the soul is directly connected, and with which it passes in generation from one being to another. This he sometimes designates as warmth, sometimes as the breath; he describes it as of nobler nature than the four elements, and as resembling ether. The solution, then, of the problem, how soul and body can constitute a single being, is that the two belong to totally different orders of existence. Like form and matter everywhere, they are distinguishable in thought, but they cannot exist separately, any more than the eye and vision can exist separately.

Plato not only distinguished three parts of the soul, but assigned to them separate seats in the body. Aristotle raises the question whether such spatial separation can consist with the unity of the soul, and decides that it cannot. He therefore contents himself with enumerating the classes into which psychical manifestations fall, and distinguishes four:

1. Nutrition and growth — the nutritive part.
2. Sensation and perception — the sensitive part.
3. Desire and locomotion — the locomotive part.
4. Thought — the rational part.

Of these four, plants possess only the nutritive soul; animals have this and the sensitive soul as well. The lowest kind of sensation is touch, and this all animals possess; with touch go always pleasure and pain. Most animals have locomotion as well as sensation, and with this desire. Man, finally, possesses in addition to the nutritive, the sensitive, and the locomotive soul the highest form of psychical activity, rational thought. It thus appears that the lower parts can occur without the higher, but not the higher without the lower. Notwithstanding these various forms of psychical activity, it is the same identical soul which manifests itself in them all. If the soul consisted of several juxtaposed pieces, it would be

held together by the body; whereas in reality the body is held together by the soul.

The central organ of psychical activity is the heart, not the brain, whose function is merely that of cooling the blood. The heart is the organ both of sensation and of locomotion. Tactual sensations are propagated to the heart through the flesh, all others through certain "channels," by which Aristotle undoubtedly means the blood-vessels, for he knows nothing of the nerves. The heart also causes the movements of the limbs.

Sensation is the most distinctive characteristic of the animal as compared with the plant. It consists in "an alteration brought about by the perceived object in the percipient subject through the medium of the body." This alteration is of such a sort that the percipient subject, functioning as matter, takes upon itself the form of the perceived object. Sense-perception may therefore be defined as the reception of the form of an object without its matter. The action of objects upon the senses always takes place through some medium; in the case of vision this medium is light, in that of hearing air, in that of smell moisture. In touch and taste there seems to be no medium, but there is one, namely the flesh, and the true organ of these senses is therefore not the skin, but the heart. The fact that by touch we perceive so many pairs of opposites—hard soft, rough smooth, dry wet, warm cold—suggests to Aristotle the doubt whether it is really a single sense; which he silences with the remark that the other senses also perceive more than one pair—hearing, for example, perceives not only differences of pitch (high low), but also differences of intensity (loud soft), roughness and smoothness of voice, etc. The senses of touch and taste are so indispensable to existence that all animals possess them. They are the lowest senses, for they minister to the lowest functions, those of nutrition and reproduction. Sight and hearing, on the other hand, stand highest, for they are the means by which the intellect is developed; and of the two, hearing is the superior sense, because upon it the communication of ideas by means of language depends. Aristotle endeavors to prove, as against Democritus, that it is impossible there should be other senses than the five.

Each of the senses yields us a kind of sensation peculiar to itself alone; for instance, vision alone yields color, smell alone odor, etc. But there are other qualities of objects which are common to the perceptions of all the senses, namely such universal qualities as number, size, and form, motion and rest, and time. Now we cannot suppose, to take an example, that the

space we see is a different space from that we touch; but if they are one and the same space, they must be perceived by one and the same faculty; and therefore not by sight nor by touch, but by some deeper-lying faculty which functions in connection with both these senses. This faculty Aristotle calls the *sensus communis*. It is this faculty by which we compare and distinguish the data of the different senses, for no single sense can compare what it perceives with what is perceived by some other sense. It is this faculty which considers our sensations as representing something objective, for the individual senses cannot judge of this, but can only feel what they feel. It is this faculty, finally, upon which self-consciousness depends, for "sight perceives only what is colored, and if sight perceived seeing, seeing would itself have to be colored."

The *sensus communis* is also the faculty of imagination and of memory. Imagination is an after-effect of sensation, a weakened form of sensation. For the commotion produced by the original impression persists in the sense-organ, and when it is again propagated to the heart, it causes a revival of the original sensation in the absence of the object that caused it. When this image is not only revived, but regarded as the copy of the previous sensation, we have memory; and the voluntary reproduction of a memory is recollection. Recollection is rendered possible by the fact that the organic motions which accompany the images of memory have a mutual connection, of such a sort that one calls up another; and the reason for this connection may lie in their similarity, their contrast, or their previous conjunction in time. Imagination, finally, furnishes the visions we see in our dreams, as well as the images that accompany thought.

Thought, or reason, is the highest of the mental faculties, and is that which distinguishes man from the lower animals. Though distinct from sense-perception, it deals with the same objects, that is, with the images which sense-perception furnishes. But it is concerned with a different aspect of them from that which occupies sense-perception, namely the generic in them. It is also concerned with relations such as likeness and unlikeness, cause and effect, form and matter, etc. Aristotle distinguishes two kinds of reason, the active and the passive, corresponding to the distinction that everywhere obtains between form and matter, and teaches that the co-operation of these two is necessary to actual thought. Thought as matter he calls the passive reason; thought as form his later followers call the active reason. To understand this somewhat difficult distinction, we must recur to Aristotle's explanation of sense-perception. As in sense-perception the human

faculty, functioning as matter, takes on the form of the external object, so in rational thought the human faculty, or passive reason, as matter, unites with the conceptual relations that are immanent in our percepts, as form, and it is these conceptual relations which Aristotle designates as the active reason. When the two unite, actual thought is the result. The strangeness of this distinction lies in the fact that Aristotle attributes the activity that manifests itself in thought to the content thought about. From this point of view it would seem less correct to say that we think thoughts than that thoughts think us. Aristotle says that the passive reason comes into existence with the body and perishes with it, and during life participates in its states. But the active reason has nothing to do with the life of the body; has no bodily organ; does not come into existence by procreation, but enters the body from without; and is therefore unaffected by the destruction of the body. The immortality of this part can have, however, little worth for the individual, for it possesses neither memory nor self-consciousness.

Though Aristotle's statements regarding the active reason may seem to mark a relapse into dualism, yet his psychology as a whole is distinctly monistic. He conceives the development of the soul as running parallel to that of the body, and his method is a biological-developmental one. He is a keen observer of mental phenomena as well as a profound metaphysician; he brings to bear upon psychology as much of anatomy and physiology as was known in his time; and he everywhere brings human into fruitful relations with animal psychology. Finally, he delivers psychology from the premature influence of ethics, recognizing that ethics depends upon psychology, not psychology upon ethics. It is these merits which make Aristotle the greatest psychologist of antiquity.

STUDIES FROM THE LABORATORY OF EXPERIMENTAL PSYCHOLOGY OF THE UNIVERSITY OF WISCONSIN.

By Joseph Jastrow, Ph. D.

I.—The Effect of Foreknowledge upon Repetition-Times.

(With the assistance of Frederick Whitton.)

The experimental contributions to the study of the effect of foreknowledge upon the times of simple mental processes may be thus briefly summanized. In simple reactions the nature of the stimulus is of course foreknown, but the precise moment of its appearance and its intensity may be left indefinite. It has been found that the omission of a preparatory signal, or an irregular interval between signal and stimulus, as also are irregular variation between more or less intense stimuli, all lengthen the simple reaction-time. In that form of a distinction-time, in which one particular stimulus is to be reacted to but all others are passed without reaction, it is found that the larger the number of possible stimuli (and therefore the less definite the foreknowledge) the longer the reaction-time. In adaptive reactions, with the number of modes of reaction constant the time will be longer as each mode of reaction is connected successively with one, with two, with three or with more and indefinitely many stimuli; the stimuli may or may not be grouped in classes. In association-times Münsterberg has shown that the preceding of a question asking for a personal preference or judgment between a pair of objects, by the mention of a dozen or so of the class of objects to which the pair belongs, decidedly shortens the time of answer to the question, in one series from 947 σ to 676 σ. [1] This last form of experiment is extremely interesting; it seems to show that although we cannot begin to say, for example, whether we prefer peaches to pears, until we have heard the full question,—"apples, plums, cherries, peaches, grapes, oranges, pears, figs, lemons, dates, apricots, pine

[1] For a more detailed account of these points see Jastrow, Time-Relations of Mental Phenomena; pp. 15-17, 39-40, 50-51, etc.

apples,—which do you prefer, peaches or pears?,"—yet the time needed for this decision is much shorter than when the introductory series of words is omitted.

The object of the present study was to test this point in a much more simple type of reaction, and with a variable number of possible stimuli. We selected for this purpose the repeating aloud of spoken words, the operator called a word and as quickly as possible the subject repeated it, all the words used being monosyllables. We found as the average of about 250 experiments with each of us that the time needed for doing this when the word might *be any word whatever*, for J. J. 269 σ for F. W. 267 σ. We formed lists of words as follows: (a) 100 very common verbs, signifying simple actions; (b) 50 common names of animals; (c) 20 proper names, such as John, Frank, Bess, Kate; (d) 20 letters (omitting b, d, m, n, v, w, as confusing in sound or polysyllabic); (e) 10 common French words; (f) the ten numbers, 'one,' 'two,' etc. to 'ten.' Only one list of each class of words was used, so that we became increasingly familiar with the lists. Before each set of 20 experiments the entire list of words from amongst which the words for repetition were to be selected, was read aloud. The following table shows for each of us the average time needed to repeat words under these circumstances. Each result expresses the average of from 240 to 300 experiments.

The conclusion thus corroborated is that *as the range of possible words decreases in extent, as the subject's expectation is more and more definite, the time needed to repeat the word becomes shorter.* It indicates the power and the utility of a general direction of the mind in the line of a more specific operation; the entrance into the general field of attention as preparatory to entering its fovea; the apperception that precedes preception, or in Galton's words, the entrance into the ante-chamber of consciousness to prepare the way for admission to the audience-chamber. We have here an adaptive reaction, each different word forming a distinct stimulus and the vocal manipulation necessary to repeat it a distinct form of reaction. It would seem that we could not get ready to repeat a word until we knew what the word is, and yet a knowledge of the possibilities of the case really aids our expectation and shortens even so simple a process as repetition. We perform the coarse adjustment before the stimulus appears, leaving only the time of the fine adjustment to be measured. There exists all degrees of definiteness and indefiniteness of expectation, of fore-knowledge, and an increase of definiteness to a certain limit brings about a shortening of the mental processes of recognition and adaptation.

While the results are too few and too variable to admit o any detailed treatment a few more special points may be pointed out as suggested though not as established. The extreme regularity of the results, the gradual decrease from repetitions of one of an indefinite number of words, to one of 100, of 50, of 20 and of 10, is doubtless accidental; the times for repeating one of 50, one of 100 or one of an indefinite number of words, for F.W. and of the latter two for J. J. are practically the same, and indicate a limit to the range of expectation. To expect one of 100 words seems scarcely a more definite attitude than to expect any word whatever. With F. W. this seems true of 50 words as well. It seems clear that it takes less time to repeat one of 20 words than one of 50 words, and least to repeat one of the ten numbers. We know the numbers so well as a class and as a series that expectation is here most definite. A French word on the other hand is relatively unfamiliar, and it takes longer to understand and repeat it. To obtain the time needed for the mental portions of the process alone, we substract the simple reaction-times from the repetition-times. How the former was obtained will be explained in a note.

Dr. Münsterberg has attempted to carry the distinction between the "motor" and the "sensory" form of reaction into complex types of reaction; indicating by the former a more special attention to the modes of reaction, by the latter a more special attention to the stimulus. Dr. Martius attempted to repeat the experiments in every detail but failed to obtain the distinction. We found it difficult to maintain this difference of attitude in repeating words, and the results (see the table above) show practically no difference in our cases between the two forms of reaction; the average of all the "motor" experiments was for J. J. 245 σ, for F. W. 249 σ, of the 'sensory' for J. J. 249 σ, for F. W. 251 σ. Even in the simple reaction the difference is slight; but in the ordinary reaction with a finger-key one of us shows the difference. J. J.'s simple reaction to a sound by closing a key with the finger is 136 σ for 'motor,' 162 σ for 'sensory'; F. W.'s 133 σ and 137 σ. While these results have probably only an individual significance, yet in our present incomplete knowledge of the true nature of the distinction between 'motor' and 'sensory' reactions, they may be worthy of record. *Note upon apparatus and method.* Our apparatus and method were gradually perfected during the course of the experiments (covering a period of eight months) and only such of our results were included in the averages given above as were obtained by the same method and seemed fairly comparable with one another. We began by attempting to speak the word and press the key

with the finger at the same moment, the subject also repeating the word and pressing the key as nearly as possible at the same moment. (We used keys of the form to be described in the next note, but later to avoid the noise the caller used a mercury key). This is also Münsterberg's method. We soon found a very strong tendency to close the key too soon, on the part of the reacter, and too late on the part of the caller; the former presses the key when the voluntary impulse is ready, when he feels that you know what the word is and what it is necessary to do to repeat it, rather than when the vocal mechanism is ready and may act. By this method our times were much too short, centering about 200 σ. The simple reaction time to a sound by closing a key with the finger was for J. J. 148 σ, for F. W. 135 σ. But it is hardly proper to subtract this from the repetion time to obtain the time of the mental process alone. To include the complete mechanical process the stimulus must be a vocal utterance with an accompanying closure of the key with the finger and the same for the reaction. After much trial we conclude to use a small bit of wood held between the teeth and attached to a spring lever, so that the slightest separation of the teeth, (always accompanying utterance) would cause the bit to fly out of the mouth and in so doing to make or break the chronoscope circuit. While the key is not free from objections, it worked very well and we could observe with it no serious tendency to anticipate the true reaction. The simple reaction-times recorded in the table were obtained with this key in the following manner: the observer always uttered the sound "ah" (explosive) and the reacter always used the same sound in reacting, so that the simple reaction includes all the mechanical parts of the process, and whatever error there is in uttering or repeating is contained in all alike. The difference between this and the repetition-time (on the average 68 σ) may thus be regarded as the pure mental repetition process. The further details of method and apparatus offer no peculiarities worthy of record.

A Novel Optical Illusion.

(With the assistance of G. W. Moorehouse.)

If before a rotating disc composed of a large sector of one color and a small sector of another, the two differing considerably in shade (e. g. a dark blue and a light yellow), a rod, held horizontally, be passed up and down, the whole disc seems broken up by horizontal parallel bands of a color similar to that present in greater proportion[1]. This illusion

[1] This illusion was first brought to my notice by Dr. Münsterberg upon my visit to his laboratory at Freiburg. I can find no reference to it in the literature accessible to me.

is especially striking when the component colors are markedly different, with the lighter color forming only a very small portion of the disc, when the disc is in very rapid rotation, the rod very slender and its motion moderately rapid. The bands appear quite as well if the movement of the rod is vertical, oblique, rotary, etc.; the effect of bending the rod into a spiral or other fanciful shape and giving it a rotary movement is especially striking, the bands always following parallel to the outline of the wire. If instead of showing but two colors the disc is composed of three or more the bands appear each composed of several colors; and if a disc composed of small sectors of the seven primary colors be rotated each band presents a rainbow-like appearance. This phenomenon seems especially remarkable when contrasted with the universal tendency of successive optical images to fuse. The mixing of colors upon a disc is itself a typical instance of such fusion. But here there is a sort of separation of colors, and that too at a high rate of rotation. For example, if two rotating discs were presented to us, the one pure white in color, and the other of ideally perfect spectral colors in proper proportion, so as to give a precisely similar white, we could not distinguish between the two; but by simply passing a rod in front of them and observing in the one case but not in the other the parallel rows of colored bands, we could at once pronounce the former to be composite, and the latter simple. In the indefinitely brief moment during which the rod interrupts the vision of the disc, the eye obtains an impression sufficient to analyze to some extent into its elements this rapid mixture of stimuli. The more detailed description and possible explanation of this illusion formed the object of our study as of the present exposition. It will conduce to brevity of description to arrange the several results of experimentation under appropriate headings.

Extent of the Illusion. The illusion appears with any pair of colors, provided only that the two are moderately different; but the resulting bands are of various degrees of distinctness according to the colors used. The result is clearest when the colors are strongly contrasted; we experimented successfully with red, yellow, blue, green, black, white, etc., in various combinations. Of a series of seven shades of green, numbers "one" and "two" were very dark, number "three" considerably lighter than "two," and the rest all very light with only slight differences between them. The bands could not be observed with a combination of "one" and "two" nor with any combination of "four," "five," "six," or "seven," but in all other combinations the contrast was sufficient to cause the illusion. By a differ-

ent method, to be described below, we succeeded in more accurately determining the amount of contrast needed to produce the illusion.

Proportions of the Component Colors. In a disc composed of dark red and light yellow, the bands could just be seen when a sector of 12° of red was combined with 348° of yellow, and remained visible with a decrease of yellow and an increase of red until only 3° of yellow and 357° of red were present. With red predominating the bands are also red but of a red *darker* than the general color of the disc; with yellow predominating the bands are yellow but of a yellow *lighter* than the resulting mixture. The darker bands are always more easily seen and clearer than the light ones, and hence a smaller sector of yellow with red than of red with yellow is needed to produce the illusion. We should infer that there would be a ratio of the two colors at which the bands would be neither darker nor lighter than the background; and in fact there is quite a range of ratios for which the bands are so nearly the color of the background that they are difficult to observe. This range differs for different combinations of colors; for our red and yellow the critical point is about 110° of red and the rest yellow. With more red than this the bands become more and more deeply red, and with less red more yellowish; to this extent the statement that the bands are of the color predominating in the disc must be modified.

Effect of the Width and the Rate of Motion of the Interrupting Rod. The general effect of an increase in the width of the interrupting rod was to render the illusion less distinct and the bands wider; moreover the illusion is more limited in range, i.e., it is confined to a narrower range of rotation rates of the disc and the like. While with a fine wire about a millimeter in diameter, the bands are sharply outlined and striking, with a stick 4 mm. in width they require somewhat of a strain to continuously observe them.

Maintaining the rotation rate of the disc as nearly constant as the clockwork that runs it will allow, we may vary the rate of passing the rod to and fro with characteristically different results. Moving the rod across the disc six inches in diameter, so that each movement from up down, and from down up, corresponded with the beat of the metronome beating 208 times per minute, the bands were about $\frac{5}{8}$ inch apart, with the metronome at 160 per minute about $\frac{1}{2}$ inch apart; with 108 per minute $\frac{1}{4}$ in.; with 80 per minute $\frac{1}{8}$ inch; with 60 per minute less than $\frac{1}{16}$ inch. In other words the bands are separated by smaller and smaller spaces as the rate of movement of the rod becomes slower and slower. The distances

between the bands were estimated by free-hand drawings and then verified by comparison with the rotating discs.

Analysis of the Factors of the Illusion. Allowing the above to suffice as a general explanation of the extent of the illusion, we may proceed to an analysis of its component factors. The factors are (a) the appearance not of one band but of several; (b) the distance between the bands; (c) the color of the bands; (d) the width of the bands; (e) the color of the interrupting rod; (f) the width of the interrupting rod; (g) the rate of movement of the interrupting rod; (h) the rotation-rate of the disc; (i) the nature and proportion of the component colors. It will thus be seen that the illusion is quite complicated. As an important step towards its explanation, we will consider first,

The Time-Relations of the Illusion. This involves the factors (a), (b), (g), (h). Before proceeding further it will be necessary to describe another method of producing the illusion, without which its explanation would have been impossible. This consists in sliding two half discs of the same color over one another leaving an open sector of any desired size up to 180° and rotating this against a background of a markedly different color, in other words we substitute for the disc composed of a large amount of one color, which for brevity we may call the "majority color," and a small amount of another, the "minority color," one in which the second color is in the background and is viewed through an opening in the first. With such an arrangement we find that we get the series of bands both when the wire is passed in front of the disc and when passed in back between disc and background; and further experimentation shows that the time relations of the two are the same[1]. (There is of course no essential difference between the two methods when the wire is passed in front of the disc.) These facts enable us to formulate our first generalization, viz., that for all purposes here relevant the seeing of a wire now against one background and then immediately against another is the same as its now appearing and then disappearing; a rapid succession of changed appearances is equivalent to a rapid alternation of appearance and disappearance. Why this is so we are unable to say, but the fact itself seems well established, and is both

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[1] Of course when the wire is passed between the disc and background the distinctness of the wire depends upon its contrast with the background; it appears of its true color modified by its appearance on the background and by the rotating disc through which it is seen, but it does not assume the contrast effects assumed by the rod moved in front of the disc. The time-relations in the two cases are the same but the color-phenomena considerably different.

novel and interesting. By this "open disc" method we are enabled to study the illusion independently of color, by having the disc of white against a white background with the rod moving between disc and background. In this case, as in the others, we see several rods or bands, and the suggestion is natural that we are dealing with the phenomena of after images; in other words we see the rod through the opening in a certain position, then for a brief time lose sight of it, then see it again in a slightly different position and so on, the after image of the one view not having faded out when the second view is obtained. If this is the true explanation of the fact that several rods are seen, then we should—with different rotation rates of disc and rod—see as many rods as multiplied by the time of one rotation of the disc would yield a constant, i.e., the time of an after image of the kind under consideration. The result of about 20 such tests with varying rates of the disc was the following:

			J.J.	*G.W.M.*
Average time of rotation of disc when	2	images of the rod were seen	.0812 sec.	.0750 sec.
" " " " "	3	" " " "	.0571 "	.0505 "
" " " " "	4	" " " "	.0450 "	.0357 "
" " " " "	5	" " " "	.0350 "	.0293 "
" " " " "	6	" " " "	.0302 "	.0262[1] "

Multiplying the number of rods by the rotation rate we get for J.J. an average time of after image of .1740 sec. (a little over $\frac{1}{6}$ sec.) with an average deviation of .0057 (=3.2%); for G.W.M. 1492 (a little over $\frac{1}{7}$ sec.) with an average deviation of .0036 (=2.6 %). An indepentent test of the time of after-image of J.J. and G.W.M. by observing when a black dot on a rotating white disc just failed to form a ring resulted in showing in every instance a longer time for the former than for the latter.[2]

It has already been observed that the distance between the bands diminishes as the rotation rate and the rate of movement of the rod increases; this suggests that the distance between the parallel bands is that moved over by the rod during one rotation of the disc. This we tested with various rates of disc and rod by spreading a pair a compasses until they seemed to span the distance between the bands. The following is a comparison of the actual and the theoretical result under this hypothesis:

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[1] There is a further point to be considered here, viz.: the size of the aperture, when nothing different is said it was 21°. We repeated some of the above experiments, however, with apertures of 10½° and of 42°, obtaining the same results.

[2] For the method of timing the disc see Note A. The rod was moved between parallel bars to the beats of a metronome.

One revolution in x seconds.	Rod moved y mm. in x sec.	Observed distance between bands in mm.
.0551	18	18
.0220	5.13	5
.0227	5.03	5
.00987	1.48	2
.0233	3.04	3.5
.0250	3.05	4
.0376	5.08	6.5

Considering the difficulties of the observation these agreements are extremely close. Having now accounted for the width of the bands, the distance between them, the fact that several are seen, it remains to examine certain general conditions of the illusion and more particularly the color factors of it.

The Color Factors of the Illusion. A brief acquaintance with the illusion sufficed to convince us that its appearance was due to contrast of some form, though the precise nature of this contrast is the most difficult point of all. It has already been observed that the two component colors must be somewhat different to produce the illusion and that the bands are darker when the majority color is darker than the minority color, and is lighter when the former is lighter. By the following device we succeeded in determining the minimum amount of difference between the colors that would produce the illusion: we used an open disc of light green (aperture 21°) in front of a back ground of the same color and used with the green disc a variable sector of black. When moving a rod in front of this combination we always observe a series of light bands due to the presence of the large amount of green with a little black, but as the black gains a certain proportion, we observe in addition a series of dark bands due to the contrast of the resulting darker green (mixture of light green and black) with the light green of the back ground. We have now only to vary the black till these darker bands may just be seen; this critical point with the colors used proved to be about 24° of black added to 315° of green, or "$\frac{1}{13}$ darker" if we may use that expression. It need hardly be added that the aperture exactly corresponds to the minority color and requires no special consideration.

Colors differ in two senses, in the fact that they are formed by different wave lengths, and that they contain more or less black. We have shown that colors differing only in the latter respect produce the illusion; it remains to be seen whether difference of color alone will produce it. We have the following evidence that it will not: (1) We were able to select a dark red and a dark blue, which did not give the illusion, but in which the substitution of slightly different red or blue, brought it out; (2) the same is true of a light green and light yellow; (3) in many cases while not succeeding in obtaining

colors that would cause the illusion to disappear, we succeeded in finding for any given color a second with which the illusion is faint, and (4) we can effect this more systematically by combining with one of a pair of colors yielding the illusion sufficient white or black to cause it to vanish. In a vague and popular sense we call a given red lighter or darker than a given blue, but the physicist (as we understand it) has no accurate determination of this impressionist estimate; perhaps for ordinary empirical purposes it would be of advantage to call two colors equally dark when they fail to give the illusion now under discussion.

There is a factor in the illusion not yet considered, viz., the color of the interrupting rod. Heretofore this has been a copper wire; and whenever the illusion is distinct the color of the wire is of very slight importance, but when it becomes difficult to observe, then wires of certain colors will produce it and of others will not. The general outcome of much experimentation with colors hardly sufficiently contrasted in shade to produce the illusion is this, that with the component colors both rather dark, whether in proportions giving a light band or a dark one, dark wires will produce it, but light ones will not, with the component colors both light, light wires will produce it but dark ones not.[1] We are unable to bring this result into harmony with the ordinary laws of contrast, and must be content to give the empirical result without explanation.

We have but one further mode of observation that sheds light on the present point. We can obtain the illusion quite as well by substituting for the disc a cylinder covered by a strip of colored paper with a small strip of another color crossing it. We happened to use a rubber band to hold the second strip in place and noticed a deep contrast band parallel to the rubber when in rotation. We substituted a lead-pencil mark for the rubber and still obtained the deep band, *this band being of the same color as the bands* produced by passing a rod before the disc or cylinder. A lead-pencil mark on the disc will have the same effect. We observed however that this appeared only when the line passed across the color present in lesser proportion, which at once suggested (conformably to the experiment with the open disc) that the bands are originated during our vision of the minority color. We tested this by fixing a strip of brass to the disc in such a way that it could be made to rotate on its own centre (by striking against a fixed point) during the rotation of the disc. This device replaced the rod and caused the illusion so long as it

[1] The different colors of wire were simply insulated wires with the colors of the insulation different.

was fixed to the minority color but not when fixed to the majority color. This offers some clue to the kind of contrast involved in the illusion but still leaves room for a satisfactory explanation.

The chief points of our study may be thus resumed:

(1.) The illusion appears whenever the component colors are moderately contrasted in shade, and the one is present in distinctly greater proportion than the other; a difference in color, but not in shade, does not produce the illusion.

(2.) For all purposes affecting the illusion (except certain points of color) alternate appearances of an object against different back grounds is equivalent to alternate appearance and disappearance of the object.

(3.) The fact that several bands are seen is due to the persistence of the after image.

(4.) The distance between the bands is the distance through which the rod has passed in one revolution of the disc.

(5.) With the majority color darker than the minority color the bands are darker than the resulting mixture, and lighter when the majorily color is the lighter.

(6.) The width and rate of movement of the rod as well as the rotation-rate of the disc determine the width of the band; the color of the rod becomes important when the illusion is diffcult to obtain, it then appearing that with the dark colors a dark rod is better, with light colors a light rod.

(7.) The bands originate during the vision of the minority color.

(8.) The contrast effect of the bands (while not satisfactorily explained) may also be obtained by a mark upon the minority color.

Accessory Apparatus for Accurate Time-Measurements.

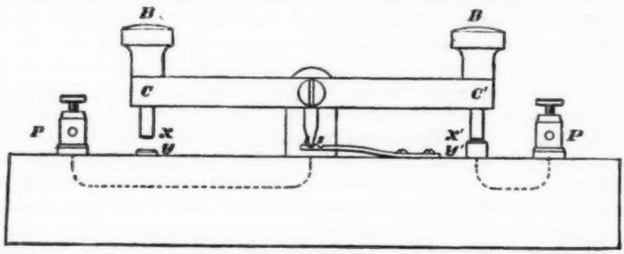
(With the Assistance of Frederick Whitton.)

A large portion of the measurement of the times of mental processes has been accomplished with the aid of the Hipp chronoscope; the objections to the use of this apparatus are the difficulty of its regulation and the possible sacrifice of accuracy to convenience. To secure accuracy, the chronoscope must be constantly controlled, and for this purpose complex devices have been resorted to for ensuring constancy of conditions and the like.[1] To simplify the method of control we

[1] The apparatus supplied with the chronoscope is altogether defective, the mechanical release of the ball is bad, the measurement of the falling height uncertain, the catch by which the circuit is closed imperfect and slow. In addition to these mechanical defects, the range of height is much too meagre. See Wundt's note to the same effect. Phys. Psych., 3d ed., II. p. 276. Note.

succeeded after many trials and failures in perfecting a piece of apparatus by which the error of the chronoscope could be readily and accurately determined. In all methods in which the control consists in timing the fall of a ball (and this too is our method), the general problem is this: two pairs of events are to occur simultaneously, first the ball to begin its fall and the hands of the chronoscope to move, and then at a definitely measurable point of the fall, the hands of the chronoscope are to stop. The difference between the present and all other methods of securing this end (and to which we think its success is due) is that this simultaneity is obtained not by allowing a magnet to release a ball and also a blade held against the action of the spring or the like, but by the use of a special form of key. A simple movement of this key serves to *make* one of two independent circuits and to break the other at the same moment. The explanation of this key will be easier if preceded by a description of the form of key used almost exclusively in this laboratory for finger reactions. It is a key that when once closed remains closed and when opened remains open; this gives the advantage of having the closing and opening movements the same, and allows this movement to be the very natural one of quickly tapping the key and then withdrawing the hand. A brass arm CC' pivoted at its centre upon a brass upright terminates above at each end in a hard rubber button BB', and below in a brass point XX'; projecting from the board upon which the whole is mounted are two brass points YY' for the purpose of making or breaking contact with XX'; finally there is fastened to the arm CC' a wedge-shaped piece of brass playing between the notches 1, 2. The key as pictured is ready to be used to break a circuit, made through the point X' connected with the binding-post P', and the point central support connected through the apparatus with the binding-post P. A simple pressure of the finger at B' breaks the contact at X' Y', and forces the wedge into the position (2), in which it is securely held by the notch (2). When in this position it is ready to be used to *make* a circuit by a pressure upon B'; it can only assume one or the other of these two positions, and in either case is securely held in place. Now imagine that the button B' instead of being of hard rubber is of brass, and imagine the end of a second brass lever at right angles to CC' in position to press down upon B' and thus establish a circuit between B' and the second lever; imagine further that the blow of this second lever upon B' is given by the release of a strong spring that holds everything firmly until X comes in contact with Y, and the apparatus is complete. A release of the spring thus establishes one circuit through B' and the second lever which sets

the chronoscope going, and at the same moment the ball begins to fall by the breaking of the circuit at $X' Y'$. The circuits are entirely independent and supplied by different batteries. To test the simultaneity we make our connections so that the making of the one circuit sets the chronoscope going and the breaking of the other stops it; and in no case did the chronoscope hands show the slightest tendency to move.



The apparatus controlling the fall of the ball is simple. An electro-magnet tapering to a point at one end is tightly held in a bracket, adjustable along a vertical slide, which in turn is securely fastened to the window frame. It is important that all parts of this be strong and securely fixed to the wall of the building. The slide is 6 to 7 feet high so that a fall of .6 to .7 seconds can be measured. From the value of g at Madison we calculate from the formula $s=\frac{1}{2} g t^{2}$ the heights at which the ball should just consume .1, .2, .3, .4, .5 and .6 seconds in its fall and mark these points on the millimeter scale along the slide, making our readings by aid of a fine wire. The ball of soft iron about $\frac{3}{4}$ of an inch in diameter is held at the tip of the magnet and in its fall strikes against the arm of a well-balanced lever, and thus severs an electrical connection by which the clock comes to a standstill; while the distance between the upper surface of the lever and the lower surface of the ball is the space fallen through in the measured time. Two further points may be noted; first to find the zero point on the scale let the magnet hold the ball and move the bracket down until the ball just touches the lever sufficiently to break the connection, and mark the point opposite the wire zero; second, use three or four thicknesses of tissue-paper between the ball and the magnet to separate the surfaces and thus diminish the time of demagnetization. With this apparatus one can without assistance take half a dozen records at different points in as many minutes; and in the work described above ten observations were recorded before and after each day's work, from which the

error of the chronoscope for the day was calculated. As the observations were taken from all six positions—.1 to .6 sec. (in the latter portion of the work for four positions) we could determine whether the error was constant or relative and found the former to be the case. Throughout a period of six months, during which the chronoscope was tested, its maximum error was .005 seconds and the average error about .002 seconds. The position of the springs regulating the chronoscope was always noted and by changing these the error could be reduced to practically zero. But we aimed not at absolute accuracy but at an accurate determination of our daily error. This apparatus has proved itself so easy of manipulation and so time-saving, that its use is confidently recommended to experimental psychologists.

Note A.—On the Timing of Rotating Discs. A simple and fairly accurate means of determining the rate of rotating discs, especially of those rotating by clockwork, has long been a desideratum. The ordinary speed-counter is out of the question on account of the great friction involved. The "interruption-counter" invented by Dr. Ewald of Strassburg is a device by which each making of an electrical circuit moves the hand of a dial just one division, the dial showing 100 divisions; its original purpose was to count the vibrations of a tuning fork and thus to serve as a convenient form of chronoscope. It is capable of counting the vibrations of a fork with a vibration-rate of 100 per second, but for this, great delicacy of manipulation is necessary. Its adaptation to the present purpose is simple, though quite a number of devices were attempted before the simple one was obtained. Two small platinized tips were soldered at opposite points on to the circumference of the wheel of the clockwork next to the one to the axle of which the disc is attached. A light brass blade, also platinized, is suspended from above with a thumb-screw regulation, so that the tips on the wheel just make a coutact with it as they pass it. As this second wheel revolves once to every eight rotations of the disc we can count to the nearest four rotations, which is quite accurate enough. By increasing the tips we can count every two or every rotation, though the adjustment must then be finer. We allow the current to run through the counter for 15 seconds (as counted by the second hand of a watch) by closing and releasing a mercury key. We also devised a method by which the timing was done automatically and so one person could observe the disc and take the time measurements as well. This consisted in fastening to the ends of an ordinary revolving drum a circular piece of paper with a strip extending over about 180° cut out; by placing the end of a fine wire

opposite this paper it is easy to arrange one's circuits so that during the time the wire touches the brass of the drum the counter is recorded, while for the rest of the revolution of the drum the current is intercepted by the paper; finally we set the drum so that the time of contact is a convenient one, say 15 sec., and when we see the contact approaching close, we lock the key and go on with our observation. The counter then of itself begins to record, does so for exactly fifteen seconds and stops; and we can make the reading at our leisure. For all these purposes the counter proved itself an exceedingly valuable apparatus.

As this is one of the first of these instruments to be used, our experience with it may be of advantage to others. Its two defects are that the wire on the magnets is too fine, thus causing an excessive resistance, and that the spring by which the magnet blade is withdrawn is not adjustable. After remedying these defects we were able to successfully manipulate the instrument with a single storage cell battery and very little trouble. We also tested the apparatus with a tuning fork of 100 per second and found it reliable. If the instrument were made as large again its efficiency would be increased.

Note on a device for color mixing. One objection to the ordinary method of mixing colors by forming sectors of them upon a disc and rapidly rotating it, is that while the mixture is produced one cannot readily compare the result with the original component colors. It is as a corrective of this defect that the following device is suggested. It consists simply of using a half disc (or any other desired portion most easily obtained by sliding two half discs or four quarter discs upon one another) of the one color and during its revolution holding the other color in back of it to one side. Then on either side you have the original colors, and where the two overlap the resulting color; if the colors be red and blue, you have before you on either side the red and blue and between them a purple. One can hold two (and with proper arrangements more) different colors in back of the same rotating disc and thus show for instance the mixture of blue with red and blue with yellow and the original blue, red and yellow all clearly displayed in line. One can show the mixture of an entire series of colors with the same color without stopping the disc, and for matching a given color with a resulting mixture this is especially convenient. With two rotating discs, overlapping upon a common background one can show the result of mixing three colors and the three original colors at the same time, but there the manipulation is no longer so simple. The method is easily adapted to the

fusion of other visual impressions and is particularly suited to class-room demonstration. A clockwork for rotating the disc is a great convenience in the experiment.

THE PSYCHOPHYSIC SERIES AND THE TIME-SENSE.

(With the assistance of W. B. CAIRNES.)

In an earlier paper reporting the studies made in this laboratory (AMER. JOURNAL OF PSYCH., Vol III, No. 1, pp. 44-49) it was shown that when we attempt to sort out sizes of sticks into six or nine magnitudes, either by the eye or by passing the finger over the sticks, the result is that the average lengths of the sticks of the several magnitudes are separated by approximately equal differences; i. e., they form an arithmetical series. This method was spoken of as that "of the psychophysic series," and consists simply in distributing according to a general impression a large variety of sense-impressions into classes or magnitudes; it is also the method by which the stars were divided into their magnitudes. If the psychophysic law holds when thus tested the result would be, as it notably is, in case of the stars[1] that the ratios of the averages of neighboring magnitudes would be constant, i. e., would form a geometrical series. A suggestion of an explanation of the applicability of the law to star magnitudes and its failure in magnitudes of extension both visual and tactual-motor, was recorded in the former study in the following words: The law may be expected to apply to "such sensations as are appreciated *en masse*, and with not too distinct a consciousness of their intensity [or extension]; when the sensation is a sort of impressionist reception of the gross sensation without dividing it up into units, or conceiving it as so composed, we may expect the law to hold good. This would be the case with the rough estimations of star brightnesses." To further test this point of view we experimented with the perception of time-intervals, in which as in the estimation of star magnitudes there is an unanalyzed appreciation of the interval, without regarding it as composed of constituent units; and for which, according to the above suggestion, the law should hold good.

Accordingly we set a metronome at one of many intervals and asked the observer after he had listened to its beating as long as he desired in order to determine his judgment, in which of *six* classes of intervals he would place it. At the outset the observer was allowed to listen to the slowest interval, 40 per minute, and to the fastest, 208 per minute, and to

[1] See the proof of this in an article Vol. I, No. I, p. 112 of this JOURNAL.

imagine this range divided up into six grades or magnitudes. At first the assignments are somewhat vague and variable but they soon became relatively fixed, though there is considerable overlapping of the various magnitudes even in the best observers. Much of this is undoubledly due to contrast, an interval following a very long one seeming shorter than it would if following a short one, and the like. We used intervals rising by 2 per minute from 40 to 120 per minute, by 3 per minute from 120 to 144, and by 4 per minute from 144 to 208, thus using in all 63 intervals. These were written on small square cards and three sets of such, or 189 cards, were used at one sitting with each observer, the cards being tossed in a box and drawn at random, and the metronome set according to the number drawn. The longest time intervals, i.e., from 1.5 seconds down were called magnitude I, and the shortest from .29 seconds up, magnitude VI; the observer sat with his back to the metronome, knew nothing of the experiment except what were the longest and the shortest intervals, and simply called out the number of the class to which he assigned the given interval. Three such full sets of nearly 200 observations were made on one observer, two each upon two others, and one each on three others, making ten in all. When the results are obtained we collect all the intervals assigned to each of the magnitudes and find the average duration of the magnitudes of that interval, which averages will serve as the basis for the present discussion.

In the accompanying table are shown for each set of observations the average number of beats per minute of each magnitude, with the number of observations contributing to that average following it in small figures the successive differences and ratios of these magnitudes, and the average of these differences and ratios together with the average deviation from them expressed in percentages. At the foot of the table a similar series of weighted averages (i. e., results of multiplying each average by the number of observations and dividing by the total number of observations), is given, combining all the observations, and this we shall first consider. To test whether the series approaches an arithmetical or a geometrical series, we have simply to compare the *constancy of the differences with that of the ratios.* This may be done with sufficient accuracy for the present purpose by finding for each of the five results the differences from their average, dividing this by five, and expressing it as a percentage of the average of the five differences, or the five ratios. We thus see that while *the average variation from a constant difference is 24.8 per cent., the average variation from a constant ratio is only 4.2 per cent., indicating a decided approximation to a*

Magnitudes.		I.	II.	III.	IV.	V.	VI.	Average.	Average Deviation	Ratio.
I.	W.B.C.	50.1^{29}	73.0^{29}	94.6^{30}	112.5^{34}	142.2^{25}	181.8^{37}			
	Differences, Ratios,	22.9 1.437	21.6 1.299	17.9 1.190	29.7 1.264	49.6 1.330		28.3 1.304	31.9% 4.9%	1 : 6.51
II.	W.B.C.	44.5^{23}	67.5^{29}	95.1^{44}	119.0^{35}	151.0^{24}	185.2^{22}			
	Differences, Ratios,	23.0 1.501	27.6 1.423	23.9 1.251	32.0 1.274	34.1 1.226		28.1 1.335	13.0% 7.6%	1 : 1.71
III.	W.B.C.	48.1^{21}	67.9^{29}	96.0^{47}	115.9^{42}	160.8^{28}	190.8^{22}			
	Differences, Ratios,	19.8 1.412	28.1 1.414	19.9 1.207	44.9 1.388	30.0 1.187		28.5 1.322	24.0% 7.5%	1 : 3.20
IV.	J. J.	48.0^{21}	64.1^{28}	89.2^{33}	106.4^{35}	140.5^{30}	186.1^{23}			
	Differences, Ratios,	16.1 1.335	25.2 1.392	17.2 1.193	34.1 1.320	45.6 1.325		27.6 1.313	35.4% 3.7%	1 : 9.57
V.	J. J.	50.6^{35}	77.7^{31}	97.6^{30}	118.5^{30}	146.0^{26}	184.1^{36}			
	Differences, Ratios,	27.1 1.535	19.9 1.256	20.9 1.214	27:5 1.232	38.1 1.261		26.7 1.300	18 8% 7.3%	1 : 2.57
VI.	R.H.T.	44.2^{9}	57.9^{29}	74.0^{27}	92.2^{44}	131.4^{42}	176.3^{44}			
	Differences, Ratios,	13.7 1.310	16.1 1.278	18.2 1.246	39.2 1.425	44.9 1.342		26.4 1.320	48.1% 3.8%	1 : 12.66
VII.	R.H.T.	44.4^{10}	54.0^{17}	81.8^{44}	105.0^{44}	132.7^{33}	178.9^{39}			
	Differences, Ratios,	9.6 1.515	27.8 1.216	23.2 1.284	27.7 1.264	46.2 1.349		26.9 1.326	31.2% 6.6%	1 : 4.73
VIII.	F. St. W.	48.1^{30}	69.4^{30}	98.0^{34}	123.6^{37}	157.6^{36}	183.1^{22}			
	Differences, Ratios,	21.3 1.443	29.6 1.427	25.6 1.261	33.4 1.270	26.1 1.166		27.2 1.313	12.6% 7.4%	1 : 1.70
IX.	S.S.B.	49.1^{24}	69.0^{31}	95.3^{46}	122.6^{35}	158.7^{29}	193.0^{23}			
	Differences, Ratios,	19.9 1.405	26.3 1.381	27.3 1.286	36.1 1.294	34.3 1.216		28.8 1.316	17.8% 4.6%	1 : 3.87
X.	S.D.J.	49.8^{29}	77.1^{33}	98.2^{35}	120.3^{40}	153.7^{33}	188.9^{29}			
	Differences, Ratios,	27.3 1.548	21.1 1.274	22.1 1.225	33.4 1.277	35.2 1.223		27.8 1.308	18.6% 7.2%	1 : 2.56
Weighted Average.	Weighted Average.	$50.0^{28\ 1}$	$69.6^{28\ 6}$	$93.6^{37\ 0}$	$114\ 3^{37\ 6}$	$147.7^{30\ 6}$	$185.1^{31\ 8}$			
	Differences, Ratios,	19 6 1.392	24.0 1.345	20.7 1.221	33 4 1.292	37 4 1.253		27.0 1.301	24.8% 4.2%	1 : 5.90

geometrical series, and therefore, according to expectation, an obedience to the psychophysic law. In the last column of all, the ratios of each pair of average deviations are given, and for the general result (accepting this rough mode of comparison), we have this, namely, that the approximation is six times (5.90) as close to a geometric as to an arithmetic series.

We may instructively note too a few peculiarities of these results; first, that while the ratios of neighboring magnitudes are approximately constant, there is a tendency for these ratios to decrease slightly from I to VI, or to increase in passing from short intervals to long ones. A precisely similar result is found in the case of star-magnitudes; and in the latter case the observations are sufficiently extended and regular to warrant an emperical formula expressing the rate of increase of this ratio, with an increase in brightness of the star-magnitudes. Moreover, two further irregularities recorded in the study of star-magnitudes reappear in the present study. The first is that at one extreme the ratio tends to be unusually large, and at the other unusually small. This is due to the limitations of the series, and the fact that were there another magnitude at each end of the series, some intervals now placed in I or VI would be placed in the class below I, or in that above VI. The errors thus induced are evidently opposite in direction. The tendency is more marked in the star observations than here, but if we note the individual results we see that in seven of ten cases the ratio of I to II is markedly larger than the others, and in five cases the ratio of V to VI is appreciably smaller than the others. These peculiarities are good evidence of the similarity of the psychological processes employed in sorting stars and in classifying time-intervals with magnitudes. A marked peculiarity of the present series (and one that interferes seriously with its regularity), is the tendency to make only a slight division between intervals assigned to III and those assigned to IV, but a marked one between those assigned to IV and those to V. This tendency is present in nine of the ten sets, and is marked in six, and so can hardly be accidental. It seems to depend upon a habit of viewing III and IV as medium intervals, while V is already a short interval. A closely similar irregularity was found in the estimations of the star-magnitudes of Ptolemy and Sufi.

Regarding the individual results we notice considerable irregularity, some individuals maintaining the law much more closely than others, as is observed most readily by a view of the last column of the table. That much of this irregularity is due to the paucity of observations is indicated by the fact that the average deviations in the combined sets I, II, III, of

W. B. C., IV, V, of J. J. and V, VI, of R. H. T., are smaller than the average of the group of three or of two sets. Thus for W. B. C.'s three sets the average variation from a constant ratio is only 4.8 per cent., in J. J.'s two sets 4.2 per cent., in R. H. T.'s two sets 3.3 per cent., while the ratios of the average variations from a constant difference and a constant ratio becomes as 1:5.54, 1:6.62 and 1:10.97. It should also be noted that the number of intervals assigned to each magnitude differs considerably. In the general average the deviation from the average of 31.3 for each magnitude is 13.4 per cent. III and IV have most intervals assigned to them (perhaps because many doubtful ones are naturally assigned to the medium magnitudes). I and II have fewest.

One further point may be mentioned as supporting the supposition that with a more conscious analysis of time-intervals, with the establishment of a habit of estimating time by seconds, the tendency to follow the geometrical series will be diminished. Thus it is quite noticeable that the first sets of all three observers who went through more than one set approach more closely to the psychophysic series than the later ones, the average deviations in the two cases being about as 4 to 7. Perhaps this is accidental, but it certainly suggests a departure from the impressionist method of estimating intervals with which we set out. Of the remaining three records VIII is unsatisfactory and was so noted at the time, while IX and X are records of observers accustomed to astronomical work, in which the second and half-second interval is important. The acquired habit of analyzing time intervals according to standard units may thus account for their slight tendency to follow the psychophysic series in their case.

The result of the present study thus goes to support the suggestion that when we estimate sensations roughly and on general impressions, without comparing them with standard units, we naturally, though unconsciously, make use of a geometrical series. We make relative distinctions rather than absolute ones, and this is the natural basis of the psychophysic law. While the process is a rough one, and is often accompanied by much hesitation and little confidence, the average results are fairly clear, and add one more to the many illustrations of the statistical regularity of apparently lawless and entirely unconscious mental tendencies.

The Psychophysic Series and the Motor Sense.

(With the assistance of Augusta A. Lee (Mrs. Charles Giddings).

As a further application of the method of the psychophysic series we experimented with a form of movement in which with the forearm supported at the elbow as a pivot the hand

moved laterally for practically any distance from 5 to 190 millimeters. The extent of the movement was limited and measured in the following way: The hand held a glass pencil and supported the same along a straight edge, the pencil furthermore moving in the ridges of very finely grooved glass. Over this glass was mounted a skeleton triangle about 6 inches across the base and 20 inches in altitude, and the whole moved in a slide to or away from the hand holding the pencil, such movement limiting the pencil to movements of varying length between the sides of the triangle and parallel to its base. A scale at the side indicated for each position of the triangle the distance moved over by the pencil. After allowing the subject to move over the shortest and the longest distances he was asked to mentally divide this range into six classes or magnitudes, and assign the various distances presented according to the perceptions gained through the sense of motion (sight was of course excluded), to the various magnitudes. Though the average lengths of these magnitudes present considerable irregularity, they very clearly show that they do not accord with the psycho-physic law and that they roughly approximate an arithmetical series. The averages themselves, together with the number of observations contributing to the average, are given in the following table:

	I.	II.	III.	IV.	V.	VI.
A. A. L. (1)	14.8 (47)	40.5 (45)	75.6 (28)	100.6 (18)	135.8 (21)	166.8 (20)
A. A. L. (2)	20.9 (42)	58.5 (34)	93.7 (26)	123.4 (15)	152.0 (12)	169.5 (13)
E.	13.5 (16)	36.6 (20)	70.7 (25)	110.7 (16)	134.8 (17)	168.6 (5)
H.	15.7 (27)	48.3 (28)	80.3 (28)	121.4 (18)	156.5 (13)	181.0 (8)
J. (1)	9.6 (22)	30.5 (44)	60.6 (45)	89.1 (33)	120.4 (24)	144.8 (39)
J. (2)	7.8 (13)	25.0 (25)	53.6 (30)	84.6 (25)	112.5 (13)	150.9 (34)

To show how far these results favor an arithmetical and how far a geometrical series it will perhaps be sufficient to state the average deviation from a constant difference and from a constant ratio of each of these series, expressed as a percentage of the average difference and the average ratio of neighboring pairs of results.

	L. (1)	L. (2)	E.	H.	J. (1)	J. (2)
Average deviation from a constant ratio—	29.8	30.7	31.1	32.5	34.9	33.7
" " " " " difference—	1.33	17.9	19.3	19.0	12.3	16.6

This shows about twice as close an approximation to an arithmetical as to a geometrical series. If however, we take the average of all six series of each magnitude we obtain a much more pronounced obedience to an arithmetical series; the successive differences become 26.2, 32.5, 32.6, 30.2, 28.3, and the average deviation of these from a constant ratio is but 8.6 per cent. of their average value. Finding the average deviation from a constant in all six series we find no such reduction. It is 30.9 per cent.

If we take into account the varying number of observations contributing to each average by weighting each difference with half the sum of the number of observations of the two averages, the difference of which is expressed, we obtain a still closer approximation to an arithmetical series. For the various series the average deviations from a constant difference then become in percentages:

L (1)	L (2)	E.	H.	J. (1)	J. (2)
10.8	18.1	19.0	13.1	12.3	17.4

and for the combined average of all only 6.3 per cent. It may be noted too that the combination of L's as of J's two sets of observations conform more closely to the arithmetical series than either one, and that the greatest deviations from the constant ratio are apt to occur in the two extremes of the series, when the shortest and when the longest lengths are concerned, the reason of which is obvious. Incomplete as these results are, they are perhaps sufficiently definite to suggest strongly the inapplicability of the physo-physic law (when thus tested), to spatial impressions gained by fore-arm movements. These movements are not altogether dissimilar to those made in running a finger along a stick (v. these studies in this JOURNAL, Vol. III, p. 47), and in both cases the judgment of length is rather conscious and referred more or less definitely to units, probably to notions gained through knowledge of feet and inches. They thus form an additional corroboration of the generalization that we conform to the requirements of the psycho-physic law in gross, *en-masse*, analyzed impressionist judgments, but not in precise detailed, analyzed and considerate judgments. The experiences of a civilized environment have transferred many forms of sense-judgment from the former to the latter class, among them spatial judgments both visual and motor. In these, absolute differences become of equal, and, at times, greater importance to us than relative ones.

THE INTERFERENCE OF MENTAL PROCESSES — A PRELIMINARY SURVEY.

(With the Assistance of W. B. CAIRNES.)

The general field with which the present study deals, (though in a somewhat eclectic and tentative manner), is the power of carrying on two mental processes at the same time. How far, we naturally ask, is this possible, how far economical? How shall we conceive this mental simultaneity, how cultivate and develop the power? We know that the shortening of mental processes brought about by practice is largely due to the power of doing two things at once, is an

overlapping of mental processes; we know, too, that when processes become automatic they may accompany more deliberate and reasoned processes without interference; and we further recognize that certain processes directed to a common end are almost as easily performed together as separately. On the other hand we observe that states of extreme concentration are characterized by immobility, even by a slackening of the automatic functions; we observe the various kinds of disturbance all indicating the interference of two or more mental processes; and we appreciate the necessity of dividing our work into small parts so that they may be easily absorbed and not over-tax our powers. In entering upon this general problem, we at once encounter the difficulty of defining the mental unit; what is a mental process? In a certain sense we are always doing two things at once; the rhythmical functions of circulation and respiration go on while we work; we walk and think, we eat and talk, we write and listen at the same time. In every game of skill several senses act at once; the eye and hand, the ear and mouth, taste and smell act together and aid one another. On the other hand, however, in an intense attention to some fascinating event we stand motionless and almost stop breathing; many persons when thoroughly interested while talking upon the street involuntarily slacken their pace, or stop altogether; few of those who illustrate their remarks by off-hand sketches can talk and draw at the same time, and so on. Our general inquiry is "What processes hinder, what aid one another;" the present study makes no attempt to answer this most important query, but simply describes a few facts and suggestions relating to a very small and special portion of the general field.

We choose as the two types of process, (1) the performance of finger movements, involving rhythm and counting, and (2) of such processes as adding and reading under various conditions. The former were written (by the usual method of a system of Marcy tambours) upon a rotating cylinder, while for the latter we simply noted the time of a set task, performed as rapidly as possible. Our records are in no case very full, and the conclusions drawn are suggestive rather than final. We will consider first the effect upon the movement of an accompanying mental task.

The chief movements used were:

(1) A regular beating with the finger at any rate the subject chose; this we speak of as an *ad libitum* movement.

(2) A movement as rapid as possible and still regular; this is a maximum movement.

(3) Beating in groups of 2s, 3s, 4s, 5s or more.

(4) Beating in alternate groups of 3s and 2s, and 6s, 4s and 2s.

(5) Keeping time to a metronome at different rates, to an air hummed to oneself, etc.

The method by which the effect of mental tasks upon these movements was estimated was to compare the *ease*, the *regularity* and the *time* of these movements when accompanied and when unaccompanied by mental operations. Our results are not sufficiently numerous to show carefully all those effects (time, ease and regularity), but in general certain tendencies are evident. The ease is shown not alone by the feeling of difficulty, but as well by the presence of errors, varying in kind and degree; so, too, even when the rhythm is maintained, it may be more or less irregular, and in turn this irregularity manifests itself in a slowing of the movements. This slowing up is the natural accompaniment of difficult processes. It will thus be seen that these three indications are closely connected with one another, each being in a measure indicative of the others and all evidencing the same points. The "normals" or times of movements with no accompanying mental process are naturally variable. The records upon six days for J. J. of an *ad libitum* movement were 335 σ, 320 σ, 318 σ, 518 σ, 388 σ, 424 σ, 326 σ, while, when several records were taken in the same day, the variations were much slighter in extent. The rate of maximum movements is much more constant, as the following records (of J. S.) show: 152, 163, 140, 148, 160, 164 σ. For beating in groups of 5 the records (of J. J.) have the following times: 1837, 1966, 1801, 1734, 1471 σ, and so on. These figures may perhaps suffice to illustrate the range of constancy of the phenomena in question.

Our first query will be: How far (neglecting for the moment the nature of the accompanying mental operation) will various movements be interfered with by the accompanying process? Our facts suggest the conclusion that the simpler movements are less interfered with than the more complex ones; the records of *ad libitum* movements show no appreciable difference when accompanied or when unaccompanied by other tasks; maximum movements are always somewhat slackened by the accompanying task; beating in groups of 2s, 3s, 4s or 5s become successively more and more interfered with by accompanying mental processes, such interference appearing not very much in a modification of time, but in the irregularity, the presence of errors (there being as a rule more beats in a group then there should be) and in the feeling of strain; in such movements as beating in groups of eleven, of alternate 3s and 2s or 6s, 4s and 2s, frequent failures set in, and when the result is fairly successful, the time is increased and the record more or less irregular. We are unable to range the

various movements in their order of relative difficulty by the amount of interference, but the extremes are very markedly differentiated.

Our second query relates to the amount of interference of different mental tasks. Reading words in construction, reading words disconnected, reading numbers and adding numbers were the chief types of processes used; of these, reading words in sentences is by far the easiest task, all the others tending to make the subject have each beat coincide with a word or addition, and thus slowing the process. Furthermore, any of the movements involving counting, (particularly alternating 3s and 2s and the like) were more interfered with by adding than by reading. But the most striking difference depends upon the manner of going through the mental process, that is, whether the reading, etc., is done aloud or to oneself. In the former case the interference sets in much sooner and is much more serious than in the latter. Even quite simple movements are rendered irregular by reading or adding aloud; and such movements as beating in 3s and 2s or 6s, 4s and 2s were practically failures in such a case, though very successfully done with silent reading. An intermediate process of mumbling seemed to yield an intermediate degree of difficulty. The interference manifests itself clearly in an increased effort, a great irregularity and presence of errors, and a lengthening of the time of movement. Motor processes thus seem to interfere with motor ones, while refraining from movement during intellectual effort would be helpful. Passing now to the effect of an accompanying movement upon the time of such operations as reading sentences, words or numbers, adding (both aloud and to oneself); our data are meagre, but the following suggested inferences, together with the facts that suggest them, may be noted.

(1) The time needed to perform these mental processes is distinctly increased by such accompanying movements, the extent of the increase depending upon the complexity of the movement. (The general average of all the records (107) shows an increase of 4.28 seconds or 30.8 per cent.; J. J., 6.5 seconds or 26.5 per cent.; W. B. C., 6.02 seconds or 36.6 per cent.)

(2) Comparing the process of adding with that of reading, the former is the more complex, and seems to be more interfered with by the accompanying movements. (Comparable records are only about a half-dozen of J. J.'s in which the percentages of increase are about as 40 per cent. to 30 per cent.

(3) Reading and adding aloud are slightly more interfered with by the movements than the same processes performed to oneself. (In six dozen records of J. J., the percentages of in-

crease in the two cases are 31 per cent. and 24 per cent.; in W. B. C., the result is obscured by other factors.)

(4) Of the effect of different kinds of accompanying movements the following may be mentioned.

(a) If the movements are rhythmical beats arranged in groups, like a line of verse or a measure of music, the time increases with the number of beats in a group. For W. B. C., with groups of 2, 3, 4, 5, 6, the times of reading the same passages were 10.4, 11.0, 13.8, 14.0, 15.4 seconds. In one case groups of eleven were attempted with an increase above the normal of about 80 per cent. A similar result appears, too, in attempting to keep time to a beating metronome every 2d, 3d, 4th or 6th stroke of which is marked by a bell, with the accented syllable to coincide with the stroke of the bell.

(b) Simple regular beating, whether to the accompaniment of a metronome or without, can be done without increase of time for reading or adding; for J. J. this is true independently of the rate of the interval. Indeed there is some evidence that a maximum rate of beating also hurries up the mental process. The movements that retarded the processes most were beating in groups of eleven, making three beats of the right hand correspond to one of the left, and beating in groups formed by a six, a four and a two in turn.

(5) Reading disconnected words is more interfered with than reading words forming sense; part of which is due to the tendency of making each word correspond to the beat. While all these points require further corroboration, our results are sufficiently suggestive to evidence the promise of research in this direction. The next step would be to make a detailed study of a few types of interference and accumulate sufficient records to allow of quantitative expression. This it is hoped will be undertaken upon some future occasion.

THE SIZE OF SEVERAL CRANIAL NERVES IN MAN AS INDICATED BY THE AREAS OF THEIR CROSS-SECTIONS.

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(From the Neurological Laboratory of Clark University.)

On several of the cranial nerves of man we have measured the areas of cross-sections, taken at definite points, and sought by this means to get a numerical expression for the size of these nerves. The immediate reason for the investigation was the desire to compare with normal material the cranial nerves of the blind deaf-mute Laura Bridgman in order to determine in her case how far these nerves departed from the normal size. The relation of the size of the cranial nerves to the other structures with which they are associated is a matter of much interest, but one to which, at the moment, we have nothing to contribute.

Little importance seems to have been attached to the size of these nerves by those authors whom we have been able to consult. In general the text books have nothing to say on the subject. Schwalbe (1), v. Gudden (2), Salzer (3) and W. Krause (4) have measured the area of the cross-section of the optic nerve in man, for the most part near the bulb, and have obtained areas as small as 7.09 sq. mm. Obersteiner(5) gives the average area as about 9 sq. mm. Since, however, our sections and theirs were not made at similar points on the nerve, a detailed comparison is unnecessary. In addition to the Bridgman specimen the material employed consisted of seven male and three female encephala. A few brief statements will be necessary by way of comment upon the Table I. in which we embody our results.

Only the first, second, third and fourth nerves have been studied. The olfactory bulb was sectioned where it was thickest. The olfactory tract where it was thinnest. The optic nerves about 10 mm. from the chiasma. The oculomotor nerves about 10 mm. from their superficial origin and the trochleares at the point where they lie on the lateral aspect of the brain stem.

In forming the table the distinction between the nerves of the right and those of the left side is neglected, but the

TABLE I.

GIVING AREAS OF THE CROSS-SECTIONS OF SEVERAL CRANIAL NERVES, NATURAL SIZE. THE UNIT OF MEASURE BEING 1 SQUARE mm.
THE NERVES ARE DESIGNATED BY THEIR SERIAL NUMBER.

Catalog Number.	Nationality.	Age.	Sex.	Weight of Encephalon with Pia in Grammes.	Cause of Death.	Autopsy, hours after Death.	Nerve I. Bulb.	Nerve I. Bulb.	Differ by	Nerve I. Tract.	Nerve I. Tract.	Differ by	Nerve II.	Nerve II.	Differ by	Nerve III.	Nerve III.	Differ by	Nerve IV.	Nerve IV.	Differ by	Remarks.
15	American.	20	Male.	1520	......	24	8.88	...	...	2.24	...	...	12.15	12.07	0.6%	5.59	4.61	12%	0.292	...	...	......
9	.....	57	"	1464	......	30	5.78	5.46	5%	1.62	1.53	5%	9.92	9.07	9%	...	...	...	...	...	...	......
10	.....	35	"	1443	Diffuse Nephritis.	22	9.50	...	...	2.37	2.32	2%	13.35	12.93	2%	2.74	2.71	1%	0.294	0.285	3%	......
13	Negro, American.	60	"	1432	......	20	9.23	...	...	4.23	3.77	12%	17.37	13.98	24%	2.04	2.04	0.4%	0.286	...	...	......
12	.....	35	"	1419	......	28	7.75	...	...	3.17	3.12	2%	12.78	12.41	2%	2.94	2.82	4%	0.358	0.329	8%	......
3	Irish.	39	"	1393	Tuberculosis	10	...	...	...	1.84	1.82	1%	12.07	11.67	3%	2.74	2.70	1%	0.778	...	...	......
2	.....	45	"	1367	Aneurism of Aorta.	18	9.09	...	...	2.86	...	...	16.32	13.03	25%	2.12	...	...	...	...	...	......
11	.....	40	Female.	1196	Phthisis.	10	...	...	...	1.06	1.05	0.3%	10.00	8.74	14%	...	2.27	...	...	...	...	......
1	Belgian.	45	"	1173	Intestinal Abcess.	18	7.65	...	...	2.59	2.57	1%	10.85	10.39	4%	3.40	3.23	4%	0.492	0.467	5%	......
14	.....	65	"	1040	......	30	8.48	6.92	22%	2.03	1.82	11%	11.61	11.17	3%	2.13	2.13	0%	0.209	...	...	General Atrophy of Encephalon.
L. B.	American.	60	"	1204	Lobar Pneumonia.	8	(r)6.34	...	...	(r)1.46	...	...	(r) 5.00	(l) 3.38	47%	(r)3.17	(l)3.51	10%	...	...	...	......

number for the larger nerve always stand first in order. To the above statement the nerves from the Bridgman brain form an exception, as in that case right and left are distinguished.

The cases have been divided according to sex and ranged in each group according to encephalic weight, with a view to bringing out any relation which might exist between sex or brain-weight and the size of the nerves. Where the two nerves of a pair have been measured there is often a large difference amounting in some cases to 25 %, as indicated in the column showing differences, expressed in percentage of the smaller member of the pair. When similar nerves from different brains are compared the differences are often much greater than between the members of the same pair. This difference in individuals corresponds with the results obtained by counting the nerve fibres in the cranial nerves—Krause([6]). Microscopical examination of the sections showed that the differences in area between the normal individuals was only to a small degree dependent on differences in the amount of connective tissue.

We conclude therefore that, while our table is too small to permit any inference concerning the relation of sex or encephalic weight to the size of the cranial nerves, we may infer some asymmetry in nerves of the same brain and a very great difference in the size of the cranial nerves in different normal individuals. When the nerves of the Bridgman brain are compared with the normals both the olfactory bulb and the tract are found to be small, but neither one is so small as in some of the normals. The optic nerves are both much smaller than any of the normals, and differ from one another in a way which will be discussed elsewhere, while the oculomotor nerves are large.

Methods Employed.

The value of the results just given depends, of course, on the reliability of the methods which were used to obtain them. It has seemed to us best to give an account of these, together with the sources of error, under a separate heading, since it could be done in this way more concisely.

It is desirable that we should be able to measure the area of a given cross-section within $\pm$ 5%, and that the cross-section which is measured should represent that of the fresh nerve, and be neither swollen nor shrunken by the treatment which it has received.

We shall first consider the method of measuring. Not having a planimeter, we adopted the method employed by v. Gudden ([2]). The mounted section was projected upon a

vertical glass plate upon which tracing paper was fastened. The outline of the picture on the tracing paper was then followed with a hard pencil; the outline in all cases being taken inside of the epineurium. The amount of enlargement was usually 25 diameters; for the smallest nerves, in some cases, about double this enlargement was used. The amount of enlargement was determined by projecting a surface ruled in squares 0.5 mm. on each side. This surface had been previously tested and the ruling found to be accurate. The parts of the projecting apparatus were rigidly fixed and the enlargement tested both before and after each set of observations. The error here depends on the accuracy with which the outline can be followed with the pencil, and amounts at most to 1 or 2 per cent. To balance this error two tracings were made from each section. The tracings were next transferred to tin foil by laying the paper over the foil and following the outline on the paper with a fine but blunt metal point, thus impressing it on the foil. The piece of foil was then cut out and weighed. Its weight divided by the weight of 1 sq. cm. of foil gave the number of square centimeters contained in it and this in turn divided by the square of the number of diameters by which it had been enlarged, gave the area of the section in its original size. If for the moment we consider the tin foil to have a uniform thickness, then the first source of error is that of impressing the outline traced on the paper, upon the foil. Next is the error due to cutting out the piece of foil. The cutting was done with a small, thin and pointed scalpel. The errors here are small and may be considered as less than 1 per cent. To balance them as far as possible each outline on the paper was twice impressed on the foil. Since each section had been twice outlined and each of these outlines twice impressed on the foil, there were finally four pieces of foil representing each section. These at first were weighed separately, to give us a notion of the amount of variation, but later in the investigation they were weighed all together, and the average taken. The weighing was done upon chemical balances weighing to tenths of mgr., and no error of importance entered these. The further reduction was simply a matter of arithmetic.

To return to the foil which is an all important factor. That used consisted of a continuous roll one foot wide. To obtain samples from this an accurately made square brass frame, enclosing an area 3 cm. on each side, was laid on the foil and the enclosed area of foil cut out with the scalpel. The weight of one sq. cm., obtained by calculation from the weight of pieces containing 9 sq. cm., was found to range between .0619 + and .0674 + grms. The average of 54 samples of the

foil showed the weight of 1 sq. cm. equal to .648 grms., which is very nearly the mean of the extremes just given. Careful testing showed that the two inches of foil on each edge of the roll gave the minimum weight, so that the greatest variation was in a line from side to side, across the roll. The difference in the extreme weight amounts to about 9% of the smaller figure—.0619 grms. This gives the impression of rather more irregularity in the foil than really occurred. If we take the 54 samples we find that 40% of them are within $\pm$ 1% of the average and that 80% are within $\pm$ 2% of the average. Since the pieces used as samples were taken, as a rule, closer to the foil representing the nerve than they were to one another and in many cases the sample was taken from within the foil representing the nerve, the amount of error introduced by the variations in the weight of the foil can be calculated as within 2%. It will thus be seen that the cumulative errors due to outlining, cutting and variations in foil might amount to 5% but the probability of their doing so in any single instance was small.

In carrying out these measurements the usual rules employed in psycho-physical work to avoid prejudicing the results were followed. The results therefore are naïve and such coincidences as occur are entirely unforced. If we knew that the section as prepared on the slide had the same area as in the natural state we might end our discussion here. Since, however, the area has been influenced by the treatment of the specimen we are compelled to give our methods in detail and estimate, as best we can, the amount of correction required.

The fresh nerves were all placed in a solution of $2\frac{1}{2}$% bichromate of potash plus $\frac{1}{6}$ its volume of 95% alcohol. In this they remained for three weeks. They were then washed for a day in water, put in 95% alcohol for 3 or 4 days and finally in 80% alcohol in which they were kept until imbedded. We have determined that the reaction to reagents of the nerve-tissues of the sheep is similar to that of man. To test then, in detail, the influence of this treatment we took similar nerves from the sheep and subjected them to like conditions. For this purpose six olfactory bulbs, six olfactory tracts, and three pairs of optic nerves from the sheep were weighed and the volume taken and then carried through the several solutions.

Thus they were prepared as the human nerves had been. Finally in 80% alcohol the volume for the olfactory bulbs was found to be 5.2% greater than in the fresh specimen, that for the olfactory tracts 8.8% greater, and that for the optics 2.6% greater. So far as we have observed the variation in volume is symmetrical for the olfactory bulbs and tracts but for the optic nerves it is not symmetrical.

In the first two instances the square of the cube root of the total enlargement will give as the area desired.

Hence for olfactory bulb,	area = 101.7%
" " tract,	" = 102.0%
" *optic nerves,	" = 105.8%

That is, the areas of the bulb, tract and optic nerves are respectively 1.7%, 2% and 5.8% more than in the nerve in its natural state. The original observations are therefore to be corrected for this increase.

Specimens were imbedded in celloidin in the usual manner. By cutting a section before imbedding, then carrying the specimen through the process and cutting another section, it was found that imbedding in celloidin did not influence the area of the section. The sections were treated as follows: stained in a solution of acid fuchsin (acid fuchsin 1 grm., 95% alcohol 80 c.c., aqua. dist. 80 c.c.) for 2 or 3 minutes, washed in water, dehydrated in 95% alcohol, and then cleared either in oleum origanum cretici or Weigert's mixture —3 parts of Xylol plus 1 part of anhydrous carbolic acid— and mounted in Xylol Balsam. Following the sections step by step through this process by taking the outline after applying each reagent, it was found that the treatment produced no change in the area. Other sections from the same specimens were stained for 5 minutes with Delafield's hæmatoxylin diluted to one-third its strength, and then dehydrated and mounted in the manner above described. After the hæmatoxylin, stain, treatment with the Xylol-carbolic clearing solution caused a well-marked swelling of the section and so an increase of area. Sections thus treated were not used for measurement and we only mention this reaction as perhaps of interest in showing the inter-dependence of the various reagents used because when the hæmatoxylin was cleared by oil of origanum the area of the section remained unchanged.

From this it was plain that in order to reduce the sections to natural size they needed to be corrected only for the swelling which had taken place in hardening the specimens. For this correction the numbers above given were used.

The only exception to this general statement was in the case of the optic nerves of Laura Bridgman which were so poor in medullary substance that it seemed fair to suppose that they would swell but very slightly, if at all, in the process of hardening and therefore the numbers which appear in the table represent the actual size of the hardened sections. The

*The method of obtaining the figure for the optic nerve will be explained in another paper.

other nerves, III and IV, in Table I, were corrected as though like the optic nerve in reaction.

It need only be added that the microtome used for making the sections permitted us to adjust the position of the object so that the sections could be cut at right angles to the axes of the nerves. Care was taken to that this was done with all possible accuracy.

A source of error exists in the determination of the part of the olfactory bulb which is thickest and the part of the tract which is thinnest, but since the pairs of sections from the same brain coincide fairly well it does not seem to us that our results are seriously affected by this disturbing factor.

We conclude therefore :

1. That the symmetrical nerves in normal brains tend to be alike.
2. That there may be great differences between individuals in the size of these nerves.
3. That the figures in the table represent within $\pm 5\%$ the areasof the several nerves reduced to their natural size.

In Laura Bridgman.

4. That the olfactory bulbs and tracts are small.
5. That the optic nerves—especially the left optic,—are very small.
6. That the 3rd nerves are normal in size.

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VISUALIZATION AS A CHIEF SOURCE OF THE PSYCHOLOGY OF HOBBES, LOCKE, BERKELEY AND HUME.

By Alexander Fraser, B. A.

Thought has often been designated, by prominent philosophical critics, a kind of natural language; but that, like language, it varies with different classes of individuals, and to what extent this fact may be regarded as the source from which arises the great variety of philosophical theory which exists in the world, has as yet been barely noticed. Just as men of different nationalities speak in different verbal languages, so do different types of individuals think in different thought-languages and, just as in the case of verbal languages, each thought-language is made up from various different sources, but has one dominant, characteristic foundation. In one type the characteristic thought-stuff may be visual, in another auditory, in another motor, and another we might perhaps conceive with Jäger to be based on the sense of smell. On every such fundamental *sensational* thought-stuff there is built up a further web of verbal thought-stuff, which consists in trains of words, each of which in turn is the name, mark, or sign of the other, and which, very much like a series of algebraic symbols, must be regarded as unknown quantities until, translated from one to another, they at last receive their values in the fundamental thought-stuff. The ordinary man never for a moment suspects the peculiar mental language in which he thinks, but lets his thoughts, however inconsistent and absurd, flow on uncriticized. His fundamental mind-stuff lies hidden beneath a veil of words. But the philosopher strips off this veil and lays bare, though not for himself yet for the critical onlooker, the true foundation. The work of the philosopher, in the light of our analogy, may be said to be the endeavor to translate the algebraic exposition of his mental life into the terms of his fundamental thought-stuff. And if such is the nature of philosophy, each distinct doctrine must be determined by, and can best be studied by becoming familiar with that particular thought-language which characterizes the mental temperament of the philosopher who presents it.

Taking this analogy as a standpoint, the object of the present paper is to offer a description and estimation of the sensationalist psychology in its first presentation by Hobbes, its development by Locke and Berkeley, and its culmination in the scepticism of Hume; in which an attempt will be made (1) to maintain that the predominating element in the thought of these men was Visualization, and (2) on the basis of this fact to offer a new criticism of the psychology of Sensationalism.

Hobbes.—Hobbes is the true precursor of Sensationalism. The following is a short summary of his psychology by Ueberweg:

"All knowledge grows out of sensations. After sensation there remains behind the memory of it, which may reappear in consciousness. The memory of objects once perceived is aided and the communication of the same to others made possible by signs, which we connect with our mental representation of these objects; for this purpose words are especially useful. The same word serves as a sign for numerous similar objects, and thereby acquires that character of generality which belongs only to words, and never to things. It depends on us to decide what objects we will always designate by the same word; we announce our decision by means of the definition. All thinking is a combining and separating, and adding and sustracting of mental representations; to think is to reckon."

Knowledge according to Hobbes has two sides. (1) Knowledge of facts, on which side, is included (a) "sensations," (b) "images," "phantasms," "remembrances," "thoughts," by all of which he means the same thing, (c) trains of images or thoughts. (2) Knowledge of the relations of facts which he calls general knowledge or science. But this second side of knowledge is not recognized as a truly mental process. It belongs to that portion of the mental language which we designated "verbal-stuff." Though he recognizes it as the highest qualification of man, yet he cannot translate it into his sensational thought-language and hence cannot agree to call it a part of the mental process.

"For besides sense and thoughts and the train of thoughts, the mind of man has no other motion; though by the help of speech and method the same faculties may be improved to such a height, as to distinguish man from all other living creatures."

It is plain from the above passage that Hobbes' sensational thought-stuff consists of these "thoughts" or "images." These are the fundamental terms in which he conceives mind to think. And all we have to do now is to ascertain to what

particular mental language they belong. To do this we need only ask Hobbes himself what he means by an "image."

"An image, in the most strict signification of the word, is the resemblance of something visible: in which sense the fantastical forms, apparitions, or seemings of visible bodies to the sight, are only *images;* such as are the show of a man, or other thing in the water, by reflection or refraction; or of the sun or stars by direct vision in the air; which are nothing real in the things seen, nor in the place where they seem to be; nor are their magnitudes and figures the same with that of the object; but changeable by the variation of the organs of sight, or by glasses, and are present often times in our imagination, and in our dreams, when the object is absent; or changed into other colors and shapes, as things that depend only upon the fancy. And these are the *images*, which are originally and most properly called *ideas*, and *idols* and derived from the language of the Grecians with whom the word Εἴδω signifieth *to see.* They also are called *phantasms*, which is in the same language, *apparitions.* And from these images it is, that one of the faculties of man's nature, is called the imagination. And from hence it is manifest, that there neither is, nor can be any image made of a thing invisible.

"It is also evident, that there can be no image of a thing infinite: for all the images, and phantasms that are made by the impression of things visible, are figured; but figure is a quantity every way determined, and therefore there can be no image of God; nor of the soul of man; nor of spirits; but only of bodies visible; that is, bodies that have light in themselves, or by such enlightened."[1]

From this it is quite evident that Hobbes identifies the whole process of imagination with that of visualization. Hear him again identifying the whole intelligible process with that of "seeing" in his interpretation of the doctrine of the "philosophy-schools."

"But the philosophy-schools . . . . teach another doctrine, and say, for the cause of vision, that the thing seen, sendeth forth on every side a *visible species*, in English, a *visible show, apparition*, or *aspect*, or *a being seen;* the receiving whereof into the eye, is *seeing.* And for the cause of *hearing*, that the thing heard, sendeth forth an *audible species*, that is an *audible aspect*, or *audible being seen;* which entering at the ear, maketh *hearing.* Nay, for the cause of *understanding* also, they say the thing understood, sendeth forth an *intelligible species*, that is, an *intelligible being seen;*

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[1] Leviathan, IV, 45.

which coming into the understanding makes us understand."

Here the only way in which he can understand the doctrine that a thing heard sends forth an audible species, is by viewing it as an "audible *being seen;*" and that a thing understood sends forth an intelligible species is by taking it to mean an "intelligible *being seen.*"

The truth of the matter is that Hobbes can hardly speak without betraying the fact that in so far as he is a psychologist he is a visualizer.

"No man therefore can conceive anything, but he must conceive it in some *place;* and indeed with some *determinate magnitude;* and which may be divided into parts."

Thus, I think, no further evidence is necessary to show that the sensationalism of Hobbes is strictly speaking only visualization.

Locke.—To Locke's philosophy, as in every other philosophy, there are two sides; there is the side which he worked out and explained and the side which he assumed but could not explain, the side which he faithfully deduced from his own original system, and the side which consists in fragments which he plucked from tradition to fill up the gaps in the former. The one is the sensational side, or rather that portion of knowledge which he succeeded in translating into his own particular kind of "sensational thought-stuff," and the other is that portion which he failed to translate and which remains in the form of "verbal thought-stuff," or untranslated "algebraic symbolism." The former is his celebrated theory of ideas and is the side which concerns us here.

According to this, all knowledge has its origin in sensation and reflection, the latter being considered as internal sensation. The endless variety and vast complex of human thought he scientifically reduces to its atoms, which he designates by the term "simple ideas." These are the "materials of our knowledge," and are "imprinted" on the senses whether we will or not. In this primary stage of knowledge the mind is "for the most part passive." Each simple idea is a distinct existence in itself, and is impressed on the mind as words are inscribed on a sheet of blank paper. There is no other source from which knowledge, however abstract and general, can come. But these ideas can be combined and permuted in an endless number of ways, which combinations are called "complex ideas." In these latter the simple ideas are not conceived of as mixed or blended, they are only conjoined; so that it is not necessary to decompose a complex idea in order to get its simple elements—it is only necessary to mechanically separate them. Consciousness, then, he makes to consist in a series of ideas which pass through the

mind, one succeeding another "at a certain distance," somewhat after the fashion of a "train;" and from this fundamental view he goes on to show how the more complex and general forms of knowledge may arise. Now the question which demands attention is, What kind of sensationalism is it that is depicted here? What sort of sensational mind-stuff is at the bottom of such a theory?

The answer might be suspected at the outset if only Locke's method be observed. His method is that of introspection, and that in the strictest signification of the word. We find him constantly using such expressions as "if we look immediately into ourselves," "when the mind turns its view inwards," and many such terms all borrowed from the sense of sight. This at once suggests visualization. But let us see how he describes the results of his introspection. Speaking of the senses he says:

Locke II, 11:2.—"These alone * * are the *windows* by which *light* is let into this *dark* room; for methinks the understanding is not much unlike a closet wholly shut from light, with only some little opening left, to let in external *visible resemblances*, or ideas of things without."

In this passage the figure used to express the whole process of the understanding is taken from the sense of sight. The same kind of figure is used in his account of attention:

Locke II, 19:3.—"Sometimes the mind fixes itself with so much earnestness on the contemplation of some objects that it *turns their ideas on all sides, remarks* their relations and circumstances, and *views* every part so nicely, and with such intention, that it shuts out all other thoughts, and takes no notice of the ordinary impressions made then on the senses, which at another season would produce very sensible perceptions; at other times it barely *observes* the *train* of ideas that succeed in the understanding without directing and pursuing any of them; and at other times it lets them pass almost quite unregarded, as *faint shadows that make no impression.*"

In his account of memory there is a remarkably strong tendency to visualization. He is constantly using such phrases as "ideas laid aside out of sight," "ideas lodged in the memory," "ideas imprinted on the memory," "dormant pictures;" and in one of the most eloquent passages of his book he describes the phenomena of forgetfulness thus:

Locke II, 10:5. "Thus the ideas, as well as children, of our youth often die before us, and our minds represent to us those tombs to which we are approaching, where though the brass and marble remain, yet the *inscriptions* are *effaced* by time, and the *imagery* moulders away. The *pictures drawn* in our minds are laid in *fading colors*, and, if not sometimes refreshed, *vanish* and *disappear.*"

In the above passage we can see his description of consciousness as it is just going out—as it is becoming "not-consciousness." And what does it amount to? Nothing more than a waning or fading of visual images. The "pictures" fade gradually, and when they have so faded as to be no longer visible they are in the realms of the forgotten—they are no longer parts of consciousness. This view of consciousness is again brought out very decidedly in his distinction between "clear" and "obscure" ideas.

Locke II, 29:2.—"The perception of the mind being most aptly explained by words relating to the sight, we shall best understand what is meant by clear and obscure in our ideas by reflecting on what we call clear and obscure in the objects of sight. Light being that which discovers to us visible objects, we give the name of obscure to that which is not placed in a light sufficient to discover minutely to us the figure and colors which are observable in it, and which in a better light would be observable. In like manner our simple ideas are clear when they are such as the objects themselves from whence they were taken did or might in a well ordered sensation or perception present them. Whilst the memory retains them thus and can produce them to the mind whenever it has occasion to consider them, they are clear ideas.

"So far as they either want any of the original exactness, or have lost any of their first freshness and are, as it were, *faded* or tarnished by time, so far they are obscure."

The "clear" idea plays an important part in Locke's psychology. Though perhaps he is not fully aware of it, it must in reality be the criterion of knowledge, as is shown in the theory as developed by Berkeley.

Again it is evident that that *static* and *passive* character of the mind, which is so striking a feature of the sensationalist psychology, is chiefly due to the influence of visualization.

Locke Essay Bk. II, 1:25.—"No man can be wholly ignorant of what he does when he thinks. These simple ideas, when offered to the mind, the understanding can no more refuse to have, nor alter, when they are *imprinted*, nor *blot them out*, and make new ones itself, *than a mirror* can refuse, alter, or obliterate the *images* or *ideas* which the objects set before it do therein produce."

Locke does attribute an active character to the mind, but it is one of those processes he cannot explain—he has to leave it in the web of "verbal thought-stuff." When he attempts to explain the activity of mind in the moral world—he distinctly implies its deadness and passivity as *intellect*. He there maintains that the "*idea* of the greatest good" cannot determine the activity of the will, but the thing necessary to such

determination is an "*uneasiness*"—the uneasiness of desire. He has to pass out from the sphere of dull, passive ideas or visual images and resort to other terms—"uneasiness."

Lastly, he speaks of consciousness as being a sort of "*train*" of ideas, each of which has a distinct existence in itself, and which, though separate and distinct, he assumes to have some sort of connection, but how or in what way he cannot discover. Now how does he come to have such a notion of the psychic process ?

Locke II, 14:9.—"I leave it to others to judge whether it be not probable that our ideas do, whilst we are awake, succeed one another in our minds *at certain distances, not much unlike the images in the inside of a lantern* turned round by the heat of a candle."

A visual figure again. I think nothing can be plainer than that this conception of thought as being a train of disconnected ideas, which have no connection in themselves but are tied together in some unknown way by some foreign tie, is just the outcome of the restriction of the whole psychic process to the partial process of visualization. In the process of vision one image comes and goes, another follows : we see both and can compare them; they may be like or unlike, but in between them is a blank—we see nothing. The visual train is a broken train: it may be connected, indeed, but the connection is not of vision—it is a foreign element. And just such we have seen to be the case with Locke's "ideas." The ideas themselves present no difficulties, but the relations of ideas are the stumbling block—they cannot be visualized and hence there is a tendency to discard them. Locke tries hard to get an idea for "Substance"—tries hard to visualize it, but he cannot, and what is the result? "It is of no use in philosophy." Again he stumbles on the threshold of natural science. Natural science looks impossible to him. "There can be no science of bodies," and why ? Because ". . . . . the simple ideas whereof our complex ideas of substances are made up, are for the most part, such as carry with them in their own nature no *visible* necessary connection."

Berkeley.—Berkeley is the first of the philosophers under consideration to state his doctrine in the terms of the analogy with which we started out. He represents the whole system of thought as a Universal Language.

"Hence it is evident that those things which, under the notion of a cause co-operating, or concurring to the production of effects, are altogether inexplicable, and run us into great absurdities, may be very naturally explained, and have a proper and obvious use assigned to them when they are

considered only as marks or signs for our information. And it is the searching after and endeavoring to understand this Language of the Author of Nature that ought to be the employment of the natural philosopher; and not the pretending to explain things by corporeal causes, which doctrine seems to have too much estranged the minds of men from that Active Principle, that Supreme and wise Spirit "in whom we live, move and have our being."[1]

But though Berkeley's aim is to apply this Natural Language to the whole extent of thought, he has not, as we shall see later, succeeded. The language which he thus tried to apply was his own particular "thought-language" and was too narrow and limited to include all phases of thought. What this mental language is, is made very explicit in the first instalment of his philosophy, the "Essay towards a New Theory of Vision." It is the language of "visible ideas."

". . . visible ideas are the language whereby the Governing Spirit on whom we depend informs us what tangible ideas he is about to imprint upon us, in case we excite this or that motion in our bodies."

At first he *consciously* extends this visual language to the whole content of thought and explicitly asserts that it is the Universal Language of Nature.

"Upon the whole, I think we may fairly conclude that the proper objects of vision constitute the Universal Language of Nature, whereby we are instructed how to regulate our actions in order to attain those things that are necessary to the preservation and well being of our bodies, as also to avoid whatever may be hurtful and destructive of them. It is by their information that we are principally guided in all the transactions and concerns of life. And the manner wherein they signify and mark out unto us the objects which are at a distance is the same with that of languages and signs of human appointment; which do not suggest the thing signified by any likeness or identity of nature but only by an habitual connection that experience has made us to observe between them."[2]

But later on in his philosophy he recognizes the vast extent of thought and the inadequacy of his language, to cover it. He therefore seeks a wider language—the language, not of '*visible ideas*' but of "ideas." What he proved true of vision he seeks to show is true of the whole phenomenal world of sense. But in this he succeeded in doing little more

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[1] Berkeley Fr. Sel. p. 69.
[2] Berkeley, Theory of Vision.

than throwing a veil over his own eyes. What he did before knowingly and explicitly, he now does blindly and implicitly. Instead of broadening his language to suit knowledge, as he thought, he only narrowed knowledge to suit his language. His final Universal Language is nothing but the same old visual language, presented in faded colors. His theory of knowledge is easily recognized as a full acceptance and more thorough development of the visualization of Locke.

"All our ideas, sensations, notions, or the things which we perceive. . . . . are VISIBLY INACTIVE—there is nothing of power or Agency included in them. So that one idea or object of thought cannot produce or make any alteration in in another."[1]

In this passage the static and inert character of the conscious process are forcibly insisted upon. The parts of thought are now strictly limited to the characteristics of visual images—they are "*visibly inactive*." And the resulting philosophy that there is no *necessary* connection, no such thing as cause and effect, existing between ideas, is for the first time strongly emphasized. Ideas can *resemble* or be like or unlike one-another, just as visual images can, but just like visual images again there can be no passage from one to the other—the '*between*' is a blank; there can be no necessary connection, no cause and effect.

From this same pictorial way of thinking arises also the denial of the possibility of knowledge of any active being, principle or relations.

"A little attention will discover to us that the very being of an idea implies *passiveness* and *inertness* in it, in so much that it is impossible for an idea to do anything, or, strictly speaking, to be the cause of anything; neither can it be the *resemblance* or *pattern* of any active being."[2]

Berkeley indeed recognized the existence of active being and relations but they are things which he cannot explain—he cannot express them from his visual point of view. We have no ideas of such, we have only some vague, far off clue to their existence—they do not come to us with the warmth of ideas, we only may be said to have some "notion" of them.

"We may be said to have some knowledge or *notion* of our own minds, of spirits and active beings, whereof in a strict sense we have not ideas. In like manner we know and have a *notion* of relations between things and ideas— . . . . To me it seems that *ideas*, *spirits*, and *relations* are all in their

[1] Berkeley, Fr. Sel. p. 45.
[2] Berkeley, Fr. Sel. p. 45.

respective kinds the object of human knowledge and subject of discourse . . . . . "[1]

Lastly, the visual character of Berkeley's mind is brought out clearly in his violent reaction against abstract ideas. For him to abstract was an insuperable difficulty.

"For my own part, whenever I attempt to frame a *simple idea* of Time, abstracted from the succession of ideas in my mind, which flows uniformly and is participated by all beings, I am lost and embrangled in inextricable difficulties. I have no notion of it at all."[2]

We need only go to his own confessions, to be convinced of his peculiar mental temperament. "I can imagine a man with too heads," he says, "or the upper parts of a man joined to the body of a horse. I can consider the hand, the eye, the nose, each by itself abstracted or separated from the rest of the body. But then whatever hand or eye I imagine, it must have some particular shape and color."

Hume.—In Hume we have the visualization psychology presented in its purest and simplest form. What Hume cannot visualize he will not admit as belonging to thought or consciousness at all, but considers as "illusion." He reduces the whole world, material and mental, to "impressions and ideas," the only difference between which being not of kind but of "force and vivacity." There is no such thing as material substance because we can have no visual expression of it. Neither, for the same reason, is there spiritual substance, nor cause and effect, nor personal identity. Mankind he regards as "nothing but a bundle of different perceptions, which succeed each other with an inconceivable rapidity, and are in a perpetual flux and movement." Between these different perceptions there is no real connection nor continuity, no underlying substance nor cause and effect, which things cannot be *seen*, but their relations consist in "resemblance" and "contiguity" for the simple reason that these can be visualized. In his figure of the "theatre" the visual character of the mind is plainly enough depicted. Consciousness is a perpetual flux of totally different distinct and disconnected perceptions and nothing more. There are not even *vague* connections which can be properly called real parts of thoughts.

"The mind is a kind of *theatre*, where several perceptions successively make their appearance, pass, re-pass, glide away, and mingle in an infinite variety of postures and situations.

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[1] Berkeley, Prin. Hum. Kno. Sec. 89.
[2] Berkeley, Prin. Sec. 98.

"The comparison must not mislead us. They are the successive perceptions *only* that constitute the mind."[1]

What more beautiful figure of visualization could we ask for than this? When I introspect I am likened unto a spectator at a theatre, where I *see* the images pass and repass, etc.," all processes recognized by vision, but with this difference that I am, as it were, on the stage myself and consequently see nothing but the characters in the play, having no view of the stage on which they act.

Taking it for granted that we have already seen sufficient particular evidence of dominant visualization in each of our authors, let us now look for a moment at one point of more general evidence.

It was discovered by Galton in his thorough investigations into the faculty of visualization that in the case of children and young people the power is usually at its best, but that as years advance, at least in the case of those who are accustomed to hard abstract thinking, it undoubtedly becomes impaired, and, to a great extent, replaced by "verbal images." Now what application can we make of this fact to the case in question? In the first place we find that Hobbes, at the time he wrote his philosophy, was an old man of sixty-four. And we also find that in him visualization, though indeed the *only* sensational part of his philosophy, was a comparatively small one. It was only a small portion of thought that he succeeded in translating into his visual mind-stuff. The web of verbal images had become so firmly woven into his mind, that, though conscious of the importance of the task, he was unable to strip it off from any of the higher processes of reason and general knowledge. He was himself fully aware of holding such a position and gave it good expression in the following passage:

"A man that hath no use of speech at all, such as is born and remains perfectly deaf and dumb, if he set before his eyes a triangle, and by it two right angles, such as are the corners of a square figure, he may by meditation compare and find that the three angles of that triangle are equal to those two right angles that stand by it. But if another triangle be shown him, different in shape from the former, he cannot know without a new labor whether the three angles of that also be equal to the same. But he that hath the use of words, when he observes, that such equality was consequent, not to the length of the sides, nor to any other particular thing in his triangle, but only to this that the sides were straight and the angles three; and that that was all for which he named it

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[1] Hume, Treat I. 4:6.

a triangle, will boldly conclude universally that such equality of angles is in all triangles whatsoever; and register his invention in these general terms, *every triangle hath its three angles, equal to two right angles.*"

Locke, too, was somewhat advanced in years when he presented his philosophical works—about the age of fifty-eight; and, as we have seen, his philosophy, like Hobbes', was under the necessity of leaving a great part of the verbal web untranslated. He tried hard to bring everything within the domain of vision, but he couldn't—his visual power being too dim, his verbal too strong.

In Berkeley and Hume we have the philosophy of youth. At the age of 25 both these men had completed their chief philosophical works. And, here again we have an illustration of Galton's results. Their powers of visualization were much higher than in the case of the former two men—so high, in fact, that they could visualize enough to make them believe that anything they couldn't visualize did not exist.

If what has already been said be true there must needs be a radical change made in the usual methods of criticizing the Humian psychology. In suggesting such a change I shall try to establish the following points: (a) The *method* of this school is right and its error consists in its incompleteness. (b) A wider sensationalism will overcome its difficulties.

(a) For our present purpose no better statement of the relative position of this psychology in the history of philosophy could be desired than that given by Professor James in that admirable chapter on "The Stream of Thought."

"If to hold fast and to observe the transitive parts of thought's stream be so hard, then the great blunder to which all schools are liable must be the failure to register them, and the undue emphasizing of the more substantive parts of the stream. . . . . Now such ignoring as this has historically worked in two ways. One set of thinkers have been led by it to *sensationalism*. Unable to lay their hands on any coarse feelings corresponding to the innumerable relations and forms of connection between the facts of the world, finding no *named* subjective modifications *mirroring* such relations, they have for the most part denied that feelings of relation exist, and many of them, like Hume, have gone so far as to deny the reality of most relations *out* of the mind as well as in it. Substantive psychoses, sensation and their copies and derivatives, juxtaposed like dominoes in a game, but really separate, everything else verbal illusion—such is the upshot of this view. The *Intellectualists*, on the other hand, unable to give up the reality of relations *extra mentem*, but equally unable to point to any distinct substantive feelings in which they

were known, have made the same admission that the feelings do not exist. But they have drawn an opposite conclusion. The relations must be known, they say, in something that is no feeling, no mental modification, continuous and consubstantial with the subjective tissue, out of which sensations and other substantives are made. They are known, these relations, by something that lies on an entirely different plane, by an *actus purus* of thought, intellect or reason, all written with capitals and considered to mean something unalterably superior to any fact of sensibility whatever."

The criticism that is generally passed on the Humian psychology is that its very foundation is unsound—that its very method, that of sensationalism, must of necessity lead to scepticism, as is so excellently illustrated in the case of Hume. It begins, it is maintained, at the wrong end of knowledge. In order to explain knowledge we must not commence with sensation, but with thought, pure and undefiled by natural processes. Sensationalism, from its essential nature, must have "breaks"—it cannot supply the 'transitive" parts of consciousness. It can find a series of conscious states, but *only* a series. There can be no continuity running through them—there can be no connecting links between them. In order to such a continuity there must be an "*actus purus*" of thought. Now whatever be the faults of this method of psychology, it will become clear enough to any one who gives the matter fair consideration, that such a criticism and proposal of amendment can make it no better. Whatever be the value of pure thought in the wider domain of philosophy, for psychology it is not only useless, but nonsense. However pure and abstracted from feeling thought may appear to the disinterested onlooker, for the thinker himself it can never be present without some degree of warmth and feeling—it must always be present in terms of that same subjective mind-stuff of which our most familiar sensations and feelings are made up. So that if the Humian psychology fails to explain knowledge and leads to scepticism, it is not, at least from the psychological point of view, because it commences at the wrong end—not because its method and fundamental groundwork carry within their own nature the sceptical germ. Its aim and method is that of a complete sensationalism—that is, to make all parts of thought consist of the same continuous subjective thought-tissue; and this is the true method of psychology. The tendency to scepticism is not the outcome of this method—at least it has not yet been shown to be. Undoubtedly the rejoinder to this will be to point to Hume as a glaring practical illustration of scepticism being a consistent and the only consistent development of the sensationalist

method. But this, I maintain, is unfair. The scepticism of Hume, as we have seen, is not the consistent outcome of *sensationalism*, but of *visualization*. It is not a philosophy resulting from being built on an unsound foundation, but from being built on one side only of a many sided foundation, and that only a particular and limited degree of that side. How a wider sensationalism both as an extension to the other senses and as a modification and more thorough development of visualization itself, may overcome many of the difficulties of Hume, will be suggested in our next point.

The psychological school which we have been considering is not only the outcome of visualization but of a particular degree of visualization. Galton in his experiments found that the degree in which this faculty exists in men is almost as varied as are the men themselves. Now if this be the case the philosophies resulting from visualization may be very different, and the faults and difficulties of one may be triumphed over in another, so that in this respect we can see the first possibility of a broader and more thorough development of sensationalism. To see the truth of this we need only resort to an illustration. Take for example the different interpretations of the concept or general ideas that have been given by visualizers:

The concept-theory with which the Humian psychology is identified is nominalism. According to this doctrine there is no general idea—the generality consists only in the name. The idea itself is some *distinct*, *particular* idea that has some time or other presented itself to the senses. It must have, Berkeley says, "some particular *shape* and *color*," and the only general quality which can be attributed to it is that it is "made to represent or stand for all other particular ideas of the same sort." This is a doctrine which results from one particular degree of visualizing power, but it is not the only one—there may be others.

In speaking of the visualizing faculty Galton says: "In the highest minds a descriptive word is sufficient to evoke crowds of shadowy associations, each striving to manifest itself. When they differ so much from one another as to be unfitted for combination into a single idea, there will be a conflict, each being prevented by the rest from obtaining sole possession of the field of consciousness. There could therefore be no definite imagery so long as the aggregate of all the pictures that the word suggested of objects presenting similar aspects, reduced to the same size, and accurately superposed, resulted in a blur. . . . . " If I mistake not, this resulting "blur" is very much like the concept described by certain upholders of conceptualism. Indeed, I think the word "blur" among the

members of this school is quite currently considered a happy term. This, then, may be considered as another modification of a visual doctrine of concepts. But this is not all—there may be others still.

Huxley, speaking of the concept, says:

"This mental operation may be rendered comprehensible by considering what takes place in the formation of compound photographs—when the images of the faces of six sitters, for example, are each received on the same photographic plate, for a sixth of the time requisite to take one portrait. The final result is that all those points in which the six faces agree are brought out strongly, while all those in which they differ are left vague; and thus what may be termed a *generic* portrait of the six in contra-distinction to a *specific* portrait of any *one* is produced."

Here we have another phase of conceptualism brought to light through the scientific conception that generic images can be imprinted on the sight after the fashion of photography. In this case the generic character does not consist in the name, it is in the idea. Neither is the idea a "blur," it is clear and distinct. To what extent this degree of visualization exists in the world I cannot say, but there can be no doubt as to its possibility.

Besides this possibility of a broader psychology by means of variations in this one sense, there is a further possibility of the same, and on a more extensive scale, in the more harmonious development and co-operation of the other senses. Not only with such men as Hume, but with almost all men, there is a proneness to identify the whole sphere of consciousness with visualization. Our very language is a good index to this fact. When we wish to convey the idea that we understand, we invariably say that we "*see.*" Again it is quite common and considered proper enough to speak of "degrees" of consciousness, some states being considered as quite "clear," others "fairly clear," and others "dim." If we have a "clear" idea of a thing we say that our consciousness of that thing is fully realized; if we have only a dim idea of it we say it is only partially realized, but that it is nevertheless all there in a potential state. Now, as is very clearly set forth by Professor James, an idea of an obscure or dim object is just as much consciousness as that of a clear one—the *consciousness*, if we are going to use the term at all, is just as "clear" in the one case as in the other. The truth is that the words "clear" and "obscure" are not properly applicable to consciousness as such. Again by a great many people the greater part of mental life—the passions, the sensations connected with the more unfamiliar senses, the motor sensations,

the visceral sensations, and perhaps many sensations connected with hearing, are not recognized as consciousness at all, all of which are in reality as truly conscious activities as the clear and distinct phenomena of vision. In this we can see the foundation of that strangely contradictory doctrine of "*unconscious mental states.*" Many of our facts of consciousness come to us, as it were, already made up. We are left only the pleasure of analyzing them; all the nice rational synthetic work seems to have been performed by some other consciousness, or perhaps to a more physiological cast of mind it may seem to have been done by the nervous system. Such activities are *known* to be mental—they could not be otherwise, but still we know that "*we*" have not been conscious of them, and hence they have been called by such names as "latent reason" and "unconscious mental states." This condition of mankind seems very much like a normal hypnotic state in which all senses excepting sight are anaesthetic; in which they perform their work, not on purely mechanical principles, but in *secondary personalities* which do not participate in the primary visual consciousness. A good illustration of this is seen in some of M. Binet's Salpêtrière subjects:

"Things placed in the hand were not felt, but *thought* of (apparently in visual terms), and in nowise referred by the subject to their starting point in the hand's sensation. A key, a knife, placed in the hand occasioned *ideas* of a key or a knife, but the hand felt nothing. Similarly the subject *thought* of the number 3, 6, etc., if the finger was bent three or six times by the operator, or if he stroked it three, six, etc., times.

"In certain individuals there was found a still odder phenomenon, which reminds one of that curious idiosyncrasy of 'colored hearing, of which a few cases have been lately described with great care by foreign writers. These individuals, namely, *saw* the impression received by the hand, but could not feel it; and the thing seen appeared by no means associated with the hand, but more like an independent vision, which usually interested and surprised the patient. Her hand being hidden by a screen, she was ordered to look at another screen and to tell of any visual image which might project itself thereon. Numbers would then come, corresponding to the number of times the insensible member was raised, touched, etc. Colored lines and figures would come, corresponding to similar ones traced on the palm; the hand itself or its fingers would come when manipulated, and finally objects would come, but on the hand itself nothing would ever be felt."[1]

It seems, just as in the cases quoted, that, the larger por-

[1] James' Psychology, part I, p. 204.

tions of our conscious life which we are liable to recognize as conscious are those which manage to translate themselves into visual terms; on which account the largest part of the content of consciousness is lost to view; all its finer connections and beautiful continuity remain, concealed in the anæsthetic senses, outside the primary consciousness, in regard to which they are blindly evolved and worked out by minor personalities.

That this is an injustice to consciousness, no proof is necessary. The remedy also is plain. It is obvious enough that what is needed for a more complete view of consciousness is a more equal emphasizing and more harmonious development of the senses. In support of the value of this suggestion I am not able to go very far. I shall only give an illustration which I hope will show the possibility of the method; and for this let us take the case of Hume, the arch-visualizer of our theme.

In the case of the passions Hume has a philosophy very different in many respects from that which he proposed for the intellect. Here he is not confronted with the difficulties with which he was surrounded in his theory of ideas—he meets with no isolated substantives which he cannot connect, but finds a beautiful continuity of consciousness; and though owing to his natural prejudice he is unable to recognize it as a process of consciousness, yet it must be considered of great value as an illustration of a more adequate view of thought being derived from other senses than that of sight. The sense he makes use of in the illustration which I refer to is that of hearing.

"Now if we regard the human mind, we shall find, that with regard to the passions, 'tis not of the nature of a wind instrument of music, which in running over all the notes immediately loses the sound after the breath ceases; but rather resembles a string-instrument where after each stroke the vibrations still retain some sound, which gradually and insensibly decays. . . . . each stroke will not produce a clear and distinct note of passion, but the one passion will always be mixed and confounded with the other. According as the probability inclines to good or evil, the passion of joy or sorrow predominates in the composition: because the nature of probability is to cast . . . . . a superior number of returns of one passion or since the dispersed passions are collected into one, a superior degree of that passion. That is, in other words, the grief and joy being intermingled with each-other, by means of the contrary views of the imagination, produce by their union the passions of hope and fear."[1]

To show how admirably this figure will allow of the proper

[1] Hume Treat. II. 9.

unity and diversity of these passions I shall quote still further.

"The passions of fear and hope may arise when the chances are equal on both sides, and no superiority can be discovered in the one above the other. Nay, in this situation the passions are rather the strongest, as the mind has then the least foundation to rest on and is tost with the greatest uncertainty. Throw in a superior degree of probability to the side of grief, you immediately see that passion diffuse itself over the composition, and tincture it with fear. Increase the probability, and by that means the grief, the fear prevails still more and more, till at last it runs insensibly, as the joy continually diminishes, into pure grief. After you have brought it to this situation diminish the grief after the same manner that you increased it; by diminishing the probability on that side and you'll see the passion clear every moment, till it changes insensibly into hope; which again runs, after the same manner, by slow degrees, into joy, as you increase that part of the composition by the increase of the probability. Are not these as plain proofs, that the passions of fear and hope are mixtures of grief and joy, as in optics 'tis a proof that a colored ray of the sun passing through a prism is a composition of two others, when as you diminish or increase the quantity of either, you find it prevail proportionably more or less in the composition?"[1]

As to the value of the illustration I shall leave it to the reader to decide. Yet I cannot refrain from remarking that in this there seems to be pictured a continuity of thought which cannot be conceived of through vision.

"In our present enthusiastic devotion to the eye it is not alone the symmetry of the mind that is threatened nor the voice arts alone that will suffer. It may be that we are neglecting that which is in itself one of the richest sources of good. It has not yet been shown that the world of form is more worthy of our cultivation than the world of sound. 'There is something as yet unanalysed about sound' says Mr. Haweis 'which doubles and intensifies at all points the sense of living: when we hear we are somehow more alive than when we see. Apart from sound, the outward world has a dream-like and unreal look—we only half believe in it; we miss at each moment what it contains. It presents, indeed, innumerable pictures of still life; but these refuse to yield up half their secrets."[2]

The starting-point of this paper was a suggestion by Dr. E. C. Sanford that I should investigate the figures of speech used in psychology. I am glad to express my indebtedness to Dr. Sanford both for this and for valuable direction in my investigations.

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[1] Hume Treat. II. 9.

[2] G. T. St. Patrick, Rivalry of the High Senses.

ANATOMICAL OBSERVATIONS ON THE BRAIN AND SEVERAL SENSE-ORGANS OF THE BLIND DEAF-MUTE, LAURA DEWEY BRIDGMAN.

HENRY H. DONALDSON, PH. D.

II.

I.— On the thickness and structure of the cerebral cortex.

PLATES III AND IV.

In a previous paper (AM. JOURN. OF PSYCHOLOGY, Vol. III, No. 3, Sept., 1890.) I have described some of the macroscopic features of the brain in question. I there stated the results of the measurements of the extent of the cortex (loc. cit. p. 336) as follows:

Extent of cortex, right hemisphere	=	98946.5 □ mm.
Extent of cortex, left hemisphere	=	101256.0 □ mm.
Total extent of cortex	=	200202.5 □ mm.

It has been recognized by all those who have studied the extent of the the cortex, that unless supplemented by observations on the thickness and character of the same, the figures for extent did not give a good ground for further inference. Jensen([45]) is, however, the only investigator who has up to this time made his studies thus complete.

It is, therefore, my purpose to report the results of the examination of the cortex of Laura Bridgman together with such conclusions as may be drawn from the results.

I.—The thickness of the cerebral cortex in general.

By way of preface I made a little excursion into the literature of the cortex to determine what was considered to be the normal thickness of that layer. It is highly probable that some of the work on this subject has escaped my notice, but what was found is tabulated (Table I.) with the purpose of showing how fully the various authors have stated the manner in which they obtained their results and what corrections had to be made, in certain cases, in order to have the results fairly comparable.

TABLE I.

Thickness of Cortex.

Date.	Authority.	Acquired defect.	No. of Brains Examined.	No. of localities in each hemisphere.	Special locality.	Average; localities not given.	Measuring Instruments.	Correction for Compasses.	Condition.	Correction for hardening.	Measurement taken in	Natural thickness of cortex in mm.	
1841	Parchappe(60)	...	...	.	Ant. lobes. Base & convexity	...	...	...	...	...	...	2.–3. 2.5–5.	Normal.
1841	Baillarger(54)	...	...	.	...	Average	...	...	Fresh (?)	...	Paris lines	3.37	
1865	Engel(55)	...	...	.	...	"	...	...	...	...	...	2.2–3.7	
1875	Jensen(45)	...	4	18	...	...	Compasses	+ 4 %	80 % alcohol	+ 2 %	...	2.91	
1878	Richet(56)	...	...	.	...	"	...	...	Fresh (?)	...	...	3.00	
1879	Bucknill and Tuke(57)	...	...		...	"	...	...	...	...	Inches	2.03	
1880	Danilewsky(49)	...	...	.	...	"	...	...	Fresh	...	...	2.50	
1884	Conti(58,59)	...	10 M.* 8 F.†	26	...	...	Compasses	+ 4 %	Fresh	...	...	2.25 M. 2.24 F.	
1886	Franceschi(61)	...	10 M. 10 F.	35	...	...	Compasses	+ 4 %	Fresh	...	...	2.48 M. 2.46 F.	
1887	Luys(62)	...	...	.	...	Average	...	...	...	...	...	3.–4.	
1888	Obersteiner(63)	...	...	.	Gyr. Post. Centr. Occipital Pole.	...	...	...	...	...	...	4. 1.5	
1891	Donaldson	...	6 M. 3 F.	14	...	...	Micrometer Eye Piece	...	Bichromate and alcohol	— 2 %	...	2.92 M. 2.91 F.	
1872	Major(64)	Insanity	4	30	...	...	Tephrylometer	...	80 % alcohol	...	Inches	2.37	Defective.
1875	Jensen(45)	" " Idiocy	2 M. 1 F. 2 F.	18	...	...	Compasses	+ 4 %	Fresh	+ 2 %	...	2.68 M. 2.79 F. 2.48 F.	
1879	Bucknill and Tuke(57)	Insanity	33 M. 30 F.		...	Average	...	...	...	...	Inches	1.88 M. 1.85 F.	
1888	Cionini(65)	Gen'l Paralysis	8 M. 2 F.	31	...	...	Compasses	+ 4 %	Fresh	...	...	1.83 M. 1.84 F.	
1891	Donaldson	Arrested developm't. L. B.	1	14	...	...	Micrometer Eye Piece	...	Bichromate and alcohol	— 2 %	...	2.59	

*M.=Male
†F.=Female

The authorities are arranged in chronological order, and in two groups: the first group containing the figures which apply to the cortex of normal persons, and the second the figures that apply to defectives. In this latter group I have only the measurements that apply to individuals with an acquired defect, as contrasted with those congenitally defective. The literature bearing on the cortex in these last has been brought together by Marchand([96]), and, though the facts are very interesting, they do not bear on our present problem and are therefore excluded.

The headings of the columns in Table I. will explain themselves, I trust, and the Table may be examined now without further explanation.

Omitting my own results, there are but six authors whose figures are of interest to us now. The manner in which the final figures in these cases have been obtained requires some explanation.

We desire to know the thickness of the cortex in its natural state, but the hardening reagents used for preserving the brain alter the thickness. In another place, I expect to make some general statements with regard to the weight and volume of nervous tissues as influenced by hardening reagents. Therefore I may state here only the results obtained, viz., that alcohol of 80% causes a decrease of 2% in the thickness of the cortex, while the bichromate and alcohol treatment (potassium bichromate $2\frac{1}{2}\%$ plus $\frac{1}{6}$ its volume of 95% alcohol for 6 to 8 weeks; washing in water for 24 hours; alcohol 95% for 2 days, and final preservation in 80% alcohol) causes an increase of 2%. As will be seen these corrections have been applied in Table I. Further, the manner of making the measurements has a very decided influence on the results. Direct experiment showed that the same localities measured with the compasses gave a thickness 4% less than when measured with a micrometer eye-piece under the microscope. There is no doubt in my mind that the microscopic method is the more accurate, hence I have corrected all the measurements made with compasses by the percentage above found.

There still remains the important question of the handling

of the figures for thickness after they are obtained. In general, the summit of a gyrus has the thickest cortex and the very bottom of the sulcus, the thinnest. In getting the thickness for any locality on the hemispheres at least two measurements, a maximum and minimum, are taken. Most investigators have measured the gyri at the points where the very thickest and very thinnest cortex was to be found, and for an average taken half the sum of these figures. The thinning of the cortex at the bottom of the sulci is, so to speak, sudden and excessive and the thinnest point deviates more from the intermediate cortex than does the thickest. Such being the case the resultant figure is somewhat too small. Conti([59]), Franceschi([61]) and Cionini([65]) give full tables and they have measured in the manner above described so that their averages represent one-half of the sum of the thickest and thinnest points in each gyrus. In the brains which I have examined the thickest portion was measured at the summit of the gyrus. The observations for the thinnest was taken at the side, about two-thirds of the distance from summit to sulcus. In making the average advantage was taken of the observation that one-third of the cortex lies at the summits of gyri and two-thirds is sunken in the sulci. The smaller figure was multiplied by 2, added to the larger figure and the sum divided by 3. As a consequence of this treatment I believe that my final average for the cortex of any particular gyrus is nearer the truth than it would be if half the sum of the thickest and thinnest points had alone been taken.

The figures which will be most useful to us can now be taken from Table I and presented in Table II, with the purpose of showing whether there is any difference in cortical thickness between males and females, or between the two hemispheres of the same brain; whether defectives correspond with normal persons; and what may be regarded as the normal thickness of the cortex.

Since the figures given in the Table II do not occur in their present form in the original tables of the authorities there quoted, I should perhaps add a word of explanation on the method by which they have been obtained.

Jensen([45]) gives a condensed statement for the normal brains, and in Table II his figures are simply corrected for the effect of alcohol and the use of compasses in measuring. His tables for the defectives are fuller and permit us to determine the averages for the two hemispheres. These are corrected in the manner above mentioned. In no case did he measure the cortex of the insula. Among the defectives one case which he gives is not entered in the table because it is that of a microcephalic.

Bucknill and Tuke([57]) give, without detail, the thickness of the normal cortex as .08 in. In a table of 63 pathological cases entered with great care and fullness, one column is devoted to the thickness of the cortex — also given without detail — in hundredths of an inch. This unit, approximately equal to .25 mm., is rather large when employed in so delicate a measurement. No statement as to the number, locality or method of their measurements is made. The cases were all adults.

Conti([59]) gives full tables. He claims twenty brains in his series. The measurements on two brains — females — are, however, so incomplete that they are not used here, hence he is credited with but eighteen brains in the table. Both hemispheres were not always examined. The total number of hemispheres represented in the table is only twenty-nine, 16 right and 13 left. His cases, principally adults, range in age from sixteen months to eighty years, but there is no evidence that the youngest cases should be excluded. Twenty-six localities in each hemisphere were measured but the cortex for the insula, if measured, is not specially recorded. In the prerolandic and post-rolandic regions only the summits of the gyri and the depths of the sulci were measured. In the rolandic region intermediate measurements on each wall of the gyri were taken. The averages were obtained by summing and dividing the figures as they stand in his tables and then correcting the final results for the use of compasses. The original measurements were made in tenths of a millimeter.

Franceschi([61]) gives full and very complete tables. He examined the cortex at 35 localities on both hemispheres of twenty brains, principally from adults of advanced age, 10

males and 10 females. The measurements taken in tenths of a millimeter, and were made at the summits of the gyri and the depths of sulci. The cortex of the insula was included. The figures in Table II. are obtained directly from those of his tables, save that they have been corrected for use of compasses.

Major([64]) tested the thickness of the cortex at thirty localities on both hemispheres of the brains of four adult insane patients, the sex not given. For each locality he gives only the mean depth using one-fifth of an inch as his unit of measure. This unit is, of course, too large. He measured the insular cortex. His figures for the cortical thickness give the mean depth without detail as to the method of obtaining the mean. The instrument used, the tephrylometer, consisted of a thin walled graduated glass tube. This was pressed into the brain substance at any desired point, then, the upper end being closed by the finger, withdrawn, when a plug of brain substance remained within the tube and on this plug the thickness of the cortex is read off by the aid of the scale etched in the tube. The figures in Table. II are the simple averages of those in his tables without any corrections. Concerning the accuracy of this method of measuring the cortex there are no observations.

Cionini([65]) presents his results from the examination of fifteen adult brains, ten males, five females, all cases of general paralysis. The number of localities was 31, but in other respects the details are similar to those in the case of Conti. It occurs, however, that in five cases, three males and two females, the tables are so incomplete that they cannot be used for averages, and hence only ten cases are represented. The figures in Table II. are obtained as in the case of Conti.

A glance at Table II. shows that in both normals and defectives the average thickness is very slightly, —.01 to —.04mm., greater in the males in five out of the six cases (larger number underlined). There is a slightly greater difference between the two hemispheres, which is in favor of the left hemisphere as the figures stand (eight out of thirteen cases). In discussing the absolute thickness of the cortex as reported we have, of course, to throw out the defectives, who are, *ipso facto*, expected to have a thinner cortex.

TABLE II.

Thickness of Cortex.

Authority.	Males. No. of Brains.	Males. Defect.	Males. Right Hemisph'e.	Males. Left Hemisph'e.	Males. Average.	Females. No. of Brains.	Females. Defect.	Females. Right Hemisph'e.	Females. Left Hemisph'e.	Females. Average.	
Jensen(45)	4	. . . .	. . . .	. . . .	2.91	. . .	. . . .	. . . .	. . . .	. . . .	
Bucknill and Tuke(57)	. . .	. . . .	. . . .	. . . .	2.03	. . .	. . . .	. . . .	. . . .	. . . .	
Conti(58-59)	10	. . . .	*2.29	2.21	†2.25	8	. . . .	2.24	2.25	2.24	
Franceschi(61)	10	. . . .	2.479	2.474	2.48	10	. . . .	2.463	2.457	2.46	Normal.
Donaldson	6	. . . .	2.91	2.94	2.92	3	. . . .	2.89	2.92	2.91	
Major(64)	‡4	Insanity	2.368	2.379	2.37	. . .	. . . .	. . . .	. . . .	. . . .	
Jensen(45)	2	Insanity	2.68	2.68	2.68	1	Insanity	2.809	2.777	2.79	
	. . .	. . . .	. . . .	. . . .	. . . .	2	Insane Idiots	2.46	2.50	2.48	
Bucknill and Tuke(67)	33	Insanity	. . . .	. . . .	1.88	30	Insanity	. . . .	. . . .	1.85	Defective.
Cionini(65)	8	General Paralysis	1.809	1.851	1.83	2	General Paralysis	1.778	1.809	1.79	
Donaldson	. . .	. . . .	. . . .	. . . .	. . . .	1	Arrested development	2.55	2.62	2.59	

* Where there are averages for the two hemispheres the larger figure is doubly underlined.
† Where there are averages for the two sexes the larger figure is underlined.
‡ Sex not given.

At the moment I have no explanation to offer of the various figures given for the absolute thickness in normal persons and will simply point out that my figures agree most closely with those of Jensen.

It appears, therefore, that the average thickness for the two sexes is nearly alike, what difference there is being in favor of the males; that the left hemisphere more often has the thicker cortex; that in defectives (not congenital) it is thinner than in normal persons, and that the figures given for the absolute thickness in normal persons are at present irreconcilable. With this I conclude the introductory study of the subject.

II. *Comparison of the cortex of Laura Bridgman with that of nine normal brains (six males; three females).*

The normal brains were obtained in New York about a year ago, and I am indebted to the courtesy of several medical gentlemen of the city for them. There is no reason to think that any of these specimens were from persons of more than average intelligence, hence on that score they are comparable with the Bridgman brain. They were hardened in the same manner that the latter was (*vide* p. 9). Samples of cortex were taken in all cases from 14 localities on each hemisphere, each locality being designated by an arbitrary number.

Plate III shows the localities with the numbers used, and is intended to take the place of a written description.

In Table III. I give the cortical areas in which the localities are situated.

All the samples from the several localities were treated in the same manner, viz.: imbedded in celloidin, cut in sections about 0.1 mm. thick and measured, unstained, under a low magnifying power. It is hardly necessary to add that all the

TABLE III.

Locality.	Cortical Area for.	Locality.	Cortical Area for.
1.	Speech motor ?	8.	Sight, sensory.
2.	Speech, motor.	9.	— ?
3.	Speech?	10.	Taste and smell, sensory.
4.	Head and eyes, motor.	11.	Sight, sensory.
5.	Arm, motor.	12.	Touch, sensory.
6.	Hearing, sensory.	13.	Leg, motor.
7.	— ?	14.	Sight, sensory.

measurements were concluded before any calculations were begun and that precaution was taken to keep the results unprejudiced.

Figures for the average thickness at each locality having been obtained from all the brains in the manner above described, the localities were arranged in order, from the thickest to the thinnest, and the tables thus formed were plotted as curves. *Vide* Plate IV.

The principal results are tabulated in Table II (under Donaldson, normals), and in Table IV a further analysis is given. The figures for males and females being separated in Table IV, those for the right and left hemispheres are given in each group and the individuals in each group are ranged according to age. This last arrangement was made to see whether they showed a decrease in cortical thickness with advancing age. Conti([58]) reports that the cortex decreases regularly from a maximum at 3 years to a minimum in extreme age. I do not pretend to discuss the question here but simply refer to the table to show that these brains when thus arranged do not exhibit a decrease.

TABLE IV.

Thickness of Cortex in Controls and in Laura Bridgman.

MALES. Arranged according to age.				FEMALES. Arranged according to age.			
Age.	Weight in grms.	R. H.	L. H.	Age.	Weight in grms.	R. H.	L. H.
35	1419	* 2.81	2.81	40	1196	2.74	2.74
35	1443	2.87	3.09	45	1173	2.80	3.00
39	1393	2.77	2.86	Adult	1312	3.12	3.02
45	1367	2.90	2.93				
57	1464	2.96	2.91				
Adult	1210	3.14	3.07				
		2.91	2.94			2.89	2.92
General Average, 2.92.				General Average, 2.90.			
Laura Bridgman,				60	1204	2.55	2.62
				General Average, 2.59			

* The underlining has the same significance as in Table II.

The cortex of the left hemisphere is in five cases the thicker, while that of the right is so in four. The maximum difference between the two hemispheres of the same individual is .22 mm. (2.87 to 3.09). The averages for the males and females are nearly alike, the males being a trifle, .02 mm., thicker.

If the results for each locality are averaged for all the controls, these averages arranged in a series from the largest to the smallest and this series plotted as a curve, then the curve has the form indicated by the continuous black ink line on Plate IV. In that curve the insula, as pointed out by Major (64), has the thickest cortex. Next follows the convex surface of the hemispheres with little variation, and then the thickness gradually decreases in the mesal, occipital and orbital cortex, in the order named. Table V gives the figures from which this curve is formed as well as the figures for the two component curves, viz.: that for the males and that for the females.

TABLE V.

Averages for each locality. All controls, I.
Averages for each locality. Controls, Male, II.
Averages for each locality. Controls, Female, III.
Unit of measure, 1 mm.

Locality.	I. Average for all Controls.	II. Average for Controls, (6) Male.	III. Average for Controls, (3) Female.
3	3.38	3.48	3.33
7	3.15	3.02	3.43
6	3.10	3.05	3.18
4	3.09	3.12	3.04
2	3.08	3.06	3.12
5	3.08	3.10	3.04
10	3.04	3.03	3.06
1	2.98	2.92	3.06
13	2.86	2.82	2.94
12	2.75	2.83	2.60
11	2.65	2.65	2.66
8	2.61	2.67	2.50
9	2.53	2.60	2.41
14	2.52	2.59	2.38
	Average,	2.92	2.91

By these figures I aim to show the normal thickness of the cortex at the given localities.

The figures which form the basis for the curve of the Bridgman brain are given in Table VI. The average thickness of this cortex (see Table IV) is 2.59 mm., which is 0.32 mm. below the average for all the females and 0.15 mm. below that for the female in whom the cortex was thinnest.

Table VI.

I. Averages of the several localities. L. B., right hemisphere.
II. Averages of the several localities. L. B., left hemisphere.
III. Averages of the several localities. L. B., both hemispheres.

Laura Bridgman.

Locality.	I. R. H.	II. L. H.	III. Average.
3	3.45	2.98	3.22
7	2.93	2.72	2.83
6	2.26	2.56	2.41
4	2.98	2.77	2.88
2	2.74	2.89	2.82
5	2.61	2.75	2.68
10	2.51	2.41	2.46
1	2.70	2.54	2.62
13	2.81	2.69	2.75
12	2.70	2.56	2.63
11	1.99	2.72	2.36
8	2.16	2.48	2.32
9	1.99	2.27	2.13
14	1.92	2.35	2.14
	Aver. 2.55	Aver. 2.62	Aver. 2.59

The curves for the Bridgman figures are plotted on Plate IV. That for the left hemisphere is indicated by a broken line (dashes), and that for the right hemisphere by the line of long and short dashes. Attending for the moment to these we observe a remarkable drop at 6; from 4 to 12 both curves are generally low with a special depression at 10, and from 12 to the end they run at different levels.

It will be seen at a glance that these two curves are fairly accordant until locality 11 is reached. Here they are widely divergent, approach somewhat at 8, again to diverge at 14.

Taking up the peculiarities of the Bridgman cortex then in the order in which they occur we find the insula (3) thinner on the left side. Both sides very thin at 6, the auditory area. Locality 2, the area for motor speech, is well developed on both sides. From 4 to 13 the development is poor, specially so at 10, area for taste and smell. At 12, the area for dermal sensations, the curve is high again, and from that point on commences the remarkable divergence in the curves of the two hemispheres, that for the left side being much higher at 11, 8 and 14, all of which are within the visual area.

Referring now to the description which I have previously given (op. cit.) of the macroscopic features of this brain, I may briefly attempt to collate them with the measurements of the cortex.

The insula (3) on the left side was found less well developed. It has the thinner cortex. *Vide* Waldschmidt([67]).

At the auditory area (6) I could not decide on any macroscopic defect, but have since determmined that the first temporal gyrus at its caudal end, especially on the right side, was abnormally slender. The cortex is decidedly thin on both sides, most markedly so on the right. At the area for motor speech, the left side showed a clear lack of development (depression), but the cortex was not particularly thin for this brain.

At 10, the area for taste and smell, there was a general lack of development, exhibited by the entire temporal lobe. This is easily explained by the slow growth of this portion of the brain, a growth which was quite incomplete at the period when Laura was taken ill (2 years). The glossopharyngeal nerves appeared normal, but the olfactory bulbs and tracts were small, though not so small as in the case of some normal persons. The thinness of the cortex at this point (10) appears therefore as a part of the general arrest in growth.

Passing now to the visual area it was noticed macroscopically that both occipital lobes were blunted, but the right side turned out in every way to be much the more defective and anomalous. Concordantly the cortex of this right side at 11, 8, and 14 is much thinner than that of the left.

It must be recalled here that although at the age of two years, Laura became completely blind in her left eye, yet she retained some remnant of vision with her right eye up to her eighth year. This has left its mark on the entire central apparatus for vision. The right optic nerve is larger than the left.

Area of cross-section of R. optic nerve = 5.00 □ mm.
" " " " " L. " " = 3.38 " "

The relation in the tracts is, of course, reversed:

Area of cross-section of R. optic tract = 3.13 □ mm.
" " " " " L. " " = 4.69 " "

On the one hand then we have loss of vision in left eye at 2 years of age, associated with the smaller optic nerve and tract—a defectively developed right occipital lobe and a thin cortex in the right visual area. On the other hand we have some vision in the right eye up to the eighth year of age, associated with the larger optic nerve and tract, the more normal occipital lobe and the thicker cortex.

The general thinning of the motor cortex I would explain in part by the absence of the fibres through which the motor areas are normally associated with the sensory areas—here defective—and in part by the smaller size of some of the cell elements and non-development of others, resulting from lack of stimuli. The defects in the visual and auditory area follow directly from the loss of the corresponding sense organs and consequent arrest of growth. When the loss is not at first complete a good deal of subsequent development is possible. Why the speech-centre has not a thinner cortex I cannot, at the moment, explain.

In considering the fact that the sensory centers are much more affected than the motor, it should be remembered that aside from the special loss due to arrest and possibly degeneration falling less on the motor than on the sensory centres, there is the physiological difference that each motor centres can be excited by way of any sensory centre, and hence, so long as any senses are left, the motor centres must be stimulated to some degree, while the destruction of the special sense-organ throws a given sensory centre quite out of function. The physiological conditions in the two cases are therefore quite different and in favor of the development of the motor side.

For reference. I introduce here several tables containing the details of the figures just given.

Table VII. gives the maximum and minimum thickness of the cortex as observed at each locality on Laura Bridgman and the nine controls. The maximum was taken at the summit of the gyrus and the minimum at the side — not at the bottom of the sulcus. The average of the maximum and minimum is obtained by doubling the minimum, adding the result to the maximum and dividing the sum by three. This average figure is given in the third column for each hemisphere. The averages at the foot of the first and second columns are obtained by dividing the sum of these columns by fourteen. All the figures in this table are corrected for hardening, so that they represent the natural thickness of the cortex. The observations for the males and females are separated.

TABLE VII.

Females.

Specimen.	BRIDGMAN.						I.						VI.						XI.					
	R. H.			L. H.			R. H.			L. H.			R. H.			L. H.			R. H.			L. H.		
Locality.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
1	2.91	2.59	2.70	3.49	2.07	2.54	2.91	2.59	2.70	3.43	3.11	3.22	3.17	2.98	3.04	3.75	3 56	3.62	3.36	2.85	3.02	3.17	2.59	2.78
2	3.30	2.46	2.74	3.23	2.72	2.89	3.56	3.24	3.35	3.36	2.72	2.93	3.88	2.91	3.23	3.24	2.91	3.02	3.24	2.79	2.94	3.56	3.11	3.26
3	3.88	3.24	3.45	3.11	2.91	2.98	3.88	2.91	3.27	3.88	3.24	3.45	3.88	3.30	3.49	3.75	3.43	3.54	3.49	2.26	2.67	3.56	2.33	2.74
4	3.24	2.85	2.98	3.40	2.46	2.77	2.98	2.39	2.59	3.69	3.24	3.39	3.43	3.24	3.30	3.24	2.91	3.02	3.11	2.52	2 72	3.36	3.11	3.19
5	3.24	2.30	2.61	3.07	2.59	2.75	3.30	2.81	2.97	3.79	3.33	3.48	3.72	2.94	3 20	3.56	3.07	3.23	2 52	2.20	2.31	3.36	2.91	3.06
6	2.91	1.94	2.26	2.91	2.39	2.56	3.62	3.36	3.45	3.75	3.24	3 41	3.88	3.49	3.62	3.30	2.59	2.83	3.36	2.98	3.11	3.49	2.26	2.67
7	3.24	2.78	2.93	2.98	2.59	2.72	3.56	3.17	3.30	3.88	3.69	3.75	3.56	3.24	3.35	3.56	3.24	3.35	3.56	3.36	3.43	3.43	3.36	3.38
8	2.59	1.94	2.16	3.04	2.20	2.48	2.91	1.94	2.26	2.91	2.01	2.31	3.17	2.98	3.04	3.24	2.39	2.67	2.72	2.26	2.41	2.39	2.26	2.30
9	2.20	1.88	1.99	2.52	2.14	2.27	2.72	1.94	2.20	3.56	2.26	2.69	3.24	2.39	2.67	2.78	2.07	2.31	2.59	1 94	2.16	2.78	2.26	2.43
10	2.84	2.35	2.51	2.75	2.24	2.41	2.85	2.14	2.38	2.59	2.26	2.37	2.88	2.91	3.23	3.75	3.11	3.32	3.88	3.56	3.67	3.88	3.11	3.37
11	2.20	1.88	1.99	2.98	2.59	2.72	3.04	2.91	2.95	3 88	2.39	2.89	3.33	2.56	2.82	3.07	2.59	2.75	2.65	1.94	2.18	2.65	2.20	2.35
12	2.91	2.59	2.70	2.65	2.52	2.56	3.11	2.07	2.42	2.91	2.65	2.74	3.75	2.52	2.93				2.91	2.39	2.56	2.59	2.20	2.33
13	3.24	2.59	2.81	3.04	2.52	2.69	3.43	3.11	3.22	3.43	2.59	2.87	3.24	2.98	3.07	3.36	2.98	3.11	3 30	2.72	2.91	2.78	2.26	2.43
14	2.14	1.81	1.92	2.91	2.07	2.35	2.59	1.94	2 16	2.72	2.39	2.50	3.04	2.59	2.74	2.72	2.33	2.46	2.78	2.07	2.31	2.46	1.94	2.11
Aver.	2.92	2.37	2.55	3.01	2.43	2.62	3.18	2 61	2.80	3.41	2.79	3.00	3.51	2.93	3.12	3.33	2.86	3.02	3.11	2.56	2.74	3 10	2.58	2.74

TABLE VII.—*Males.*

Specimen	II.						III.						IV.					
	R. H.			L. H.			R. H.			L. H.			R. H.			L. H.		
Locality.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
1	3.04	2.65	2.78	3.30	2 20	2.57				3.24	2.91	3.02						
2	3.36	2.91	3.06	3.56	3.11	3.26	3.24	3.11	3.15	3.11	2.98	3.02	3.49	2.91	3.10	3.24	3.17	3.19
3	3.56	2.91	3.13	3.88	3.88	3.88	3.88	2.91	3.23	3.56	2.91	3.13	3.24	2.75	2.91	3.88	3.36	3.53
4	3.24	3.17	3.19	3.24	2.98	3.07	3.11	2.72	2.85	3.24	2.59	2.81	3.81	3.56	3.64	3.69	3.24	2.39
5	3.56	2.91	3.13	3.40	2.73	2.95	3.30	2.75	2.93	3.36	2.65	2.89	3.56	3.30	3.39	3.56	3.24	3.35
6	3.56	3.11	3.26	3.56	3.11	3.26	3.56	3.24	3.35	3.24	2.91	3.02	3.88	3.17	3.41	3.56	2.91	3.13
7	3.11	2.91	2.98	3.43	2.39	2.74	2.91	2.59	2.70	3.36	3.24	3.28	3.88	3.24	3.45	3.56	3.43	3.47
8	2.78	2.59	2.65	2.59	2.20	2.33	2.59	2.26	2.37	2 91	2.59	2.70	3.17	2.91	3.00	2.85	2.59	2.68
9	2.91	1.94	2.26	2.65	2.39	2.48	2.59	2.20	2.33	2.72	2.01	2.25	3.24	2.91	3.02	3.24	2.72	2.89
10	3.11	2.91	2.98	3.56	2.78	3.04	3.88	3.24	3.45	3.24	3.24	3.24	3.88	3.56	3.67	3.56	2.91	3.13
11	3.56	3.11	3.26	3.30	2.65	2.87	2.39	1.94	2.09	2.91	2.65	2.74	3.24	2.71	2.89	2.58	2.07	2.24
12	3.36	2.26	2.63	3 36	3.11	3.19	3.24	2.59	2.81	2.85	2.39	2.54	3.24	2.59	2.81	3.49	3.24	3.32
13	3.36	2.59	2.85	3.36	2.59	2.85	2.91	2.26	2.48	2.65	2.52	2.56	3.24	2.85	2.98			
14	2.59	2.39	2.46	2.65	2.46	2.52	2 52	2.07	2.22	2.91	2.72	2.78	3.04	2.39	2.61	2.59	2.39	2.46
Aver.	3.22	2.74	2.90	3.27	2.76	2.93	3.09	2.61	2.77	3.09	2.74	2.86	3.45	2.99	3.14	3.32	2.94	3.07

TABLE VII.—*Males.*

Specimen	IX.						X.						XII.					
	R. H.			L. H.			R. H.			L. H.			R. H.			L. H.		
Locality.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
1	3.56	2.80	3.05	3.24	2.33	2.63	2.98	2.78	2.85	3.49	3.30	3.36	3.36	2.91	3.06			
2	3.69	3.36	3.47	3.36	2.98	3.11	2.59	2.26	2.37	3.11	2.65	2.80	3.24	2.78	2.93	3.56	3.11	3.26
3	4.01	3 88	3.92	3.88	3.49	3.62	3.88	3.56	3.63	3.88	3.56	3.67	3.88	3.56	3.66	3.56	3.36	3.43
4	3.17	2.91	3.00	3.36	2.91	3.06	3.49	3.17	3.28	3.43	3.24	3.30	3.11	2.59	2.76	3.56	2.78	3.04
5	3.23	2 98	3.06	3.49	2.91	3.10	3.24	2.91	3.02	3.88	3.43	3.58	3.56	2.91	3.13	3.24	2.39	2.67
6	3.56	2.33	2.74	3.24	3.17	3.19	3.11	2.72	2.85	2.72	2.59	2.63	3.49	3.11	3.24	3.17	2.26	2.56
7	3.88	2.91	3 23	3.36	2.72	2.93	3.56	2.65	2.95	3.69	2.52	2.91	2 59	2.39	2.46	3.36	2.98	3.11
8	3.24	2.65	2.85	3.56	2.26	2.69	2.98	2.52	2.67	3.30	2.85	3.00	2.78	2.33	2.48	2.91	2.46	2.61
9	2.91	2.59	2.70	2.85	2.46	2.59	2.72	2.59	2.63	2.85	3.34	3.18	2.72	2.39	2.50	2.59	2.20	2.33
10	3.24	2.65	2.85	2.91	2.39	2 56	2.59	2.39	2.46	3.88	3.30	3.49	3.24	2.59	2.81	3.36	2.47	2.73
11	2.46	2.39	2.41	3.11	2.39	2.63	3.36	2.59	2.85	3.43	2.59	2.87	3.11	2.26	2.54	2.59	2.33	2.42
12	3.30	2.59	2.83	3.36	2.52	2.80	2.65	2.46	2.52	3.36	2.78	2.97	3.36	2.26	2.63	3.43	2.59	2.87
13	3.30	2.72	2.91	3.56	3.24	3.35	3.11	2.98	3.02	3.49	2.24	2.66	3.88	2.33	2.85	2.72	2.46	2.55
14	2.91	2.14	2.40	2.59	2.39	2.46	3.11	2.98	3.02	3.04	2.72	2.83	2.59	2.26	2.37	3.56	2.72	3.00
Aver.	3.32	2.78	2.96	3.28	2.73	2.91	3.10	2.75	2.87	3.40	2.94	3.09	3.21	2.62	2.81	3.20	2.62	2.81

Table VIII. is derived from Table VII. by arranging the figures for the average thickness of each locality in each hemisphere in vertical columns, and getting the averages of these for the females alone, for the males alone, and for both together.

TABLE VIII. *Controls Only.*

Locality.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.		
	2.70	3.35	3.27	2.59	2.97	3.45	3.30	2.26	2.20	2.38	2.95	2.42	3.22	2.16	I R.	Females.
	3.22	2.93	3.45	3.39	3.48	3.41	3.75	2.31	2.69	2.37	2.89	2.74	2.87	2.50	I L.	
	3.04	3.23	3.49	3.30	3.20	3.62	3.35	3.04	2.67	3.23	2.82	2.93	3.07	2.74	VI R.	
	3.62	3.02	3.54	3.02	3.23	2.83	3.35	2.67	2.31	3.32	2.75		3.11	2.46	VI L.	
	3.02	2.94	2.67	2.72	2.31	3.11	3.43	2.41	2.16	3.67	2.18	2.56	2.91	2.31	XI R.	
	2.78	3.26	2.74	3.19	3.06	2.67	3.38	2.30	2.43	3.37	2.35	2.33	2.43	2.11	XI L.	
Average: Females.	3.06	3.12	3.33	3.04	3.04	3.18	3.43	2.50	2.41	3.06	2.66	2.60	2.94	2.38		
	2.78	3.06	3.13	3.19	3.13	3.26	2.98	2.65	2.26	2.98	3.26	2.63	2.85	2.46	II R.	Males.
	2.57	3.26	3.88	3.07	2.95	3.26	2.74	2.33	2.48	3.04	2.87	3.19	2.85	2.52	II L.	
		3.15	3.23	2.85	2.93	3.35	2.70	2.37	2.33	3.45	2.09	2.81	2.48	2.22	III R.	
	3.02	3.02	3.13	2.81	2.89	3.02	3.28	2.70	2.25	3.24	2.74	2.54	2.56	2.78	III L.	
		3.10	2.91	3.64	3.39	3.41	3.45	3.00	3.02	3.67	2.89	2.81	2.98	2.61	IV R.	
		3.19	3.53	3.39	3.35	3.13	3.47	2 68	2.89	3.13	2.24	3.32		2.46	IV L.	
	3.05	3.47	3.92	3.00	3.06	2.74	3.23	2.85	2.70	2.85	2.41	2.83	2.91	2.40	IX R.	
	2.63	3.11	3.62	3.06	3.10	3.19	2.93	2.69	2.59	2.56	2.63	2.80	3.35	2.46	IX L.	
	2.85	2.37	3.63	3.28	3.02	2.85	2.95	2.67	2.63	2.46	2.85	2.52	3.02	3.02	X R.	
	3.36	2.80	3.67	3.30	3.58	2.63	2.91	3.00	3.18	3.49	2.87	2.97	2.66	2.83	X L.	
	3.06	2.93	3.66	2.76	3.13	3.24	2.46	2.48	2.50	2.81	2.54	2.63	2.85	2.37	XII R.	
		3.26	3.43	3.04	2.67	2.56	3.11	2.61	2.33	2.73	2.42	2.87	2.55	3.00	XII L.	
Average: Males.	2.92	3.06	3.48	3.12	3.10	3.05	3.02	2.67	2.60	3.03	2.65	2.83	2.82	2.59		
Average: Males and Females.	2.98	3.08	3.38	3.09	3.08	3.10	3.15	2.61	2.53	3.04	2 65	2.75	2.86	2.52		

Table IX. gives the difference in the thickness of the cortex in the two hemispheres of those controls in which the difference is greatest. The figures on which this table is based are found in the "average" columns of Table VII. The controls are grouped into males and females and the instance of greatest dlfference found for each group. To be compared with this is the difference in the same localities in the Bridgman brain. The figures for fhe latter show that the differences are much within the extremes of the controls

except at those localities where the largest difference is to be expected i. e., 3, 8, 11, 14—where they may exceed those of the controls. The roman numeral indicates the number of the specimen and the side which is larger is first designated, so that VI L.-VI R. means that the left hemisphere has the thicker cortex in control VI. It is not without interest in this case that among the females, 9, and among the males, 11 out of the 14 cases have the left cortex the thicker.

TABLE IX.

Greatest Differences in Cortical Thickness.

	Females.		Males.		L. B.	
Loc.	Gr. Diff.	Specimen.	Gr. Diff.	Specimen.	Gr. Diff.	
1.	.58	VI L.—VI R.	.51	X L.—X R.	.16	R. L.
2.	.42	I R.—I L.	.43	X L.—X R.	.15	L. R.
3.	.18	I L.—I R.	.75	II L.—II R.	.47	R. L.
4.	.80	I L.—I R.	.28	XII L.—XII R.	.21	R. L.
5.	.75	XI L.—XI R.	.56	X L.—X R.	.14	L. R.
6.	.79	VI R.—VI L'	.68	XII R.—XII L.	.30	L. R.
7.	.45	I L.—I R.	.65	XII L.—XII R.	.21	R. L.
8.	.37	VI R.—VI L.	.33	X L.—X R. III L.—III R.	.32	L. R.
9.	.49	I L.—I R.	.55	X L.—X R.	.28	L. R.
10.	.30	XI R.—XI L.	.54	IV R.—IV L.	.10	R. L.
11.	.17	XI L.—XI R.	.65	III L.—III R. IV R.—IV L.	.73	L. R.
12.	.32	I L.—I R.	.56	II L.—II R.	.14	R. L.
13.	.48	XI R.—XI L.	.44	IX L.—IX R.	.12	R. L.
14.	.34	I L.—I R.	.63	XII L.—XII R.	.43	L. R.

III.—Histological Examination.

The Bridgman brain was not well enough preserved to admit of a very fine microscopical examination. Some points can be made out, however, on sections .02 mm. thick, stained with hæmatoxylin and eosin, or hæmatoxylin and carminic acid, or with Weigert-Pal hæmatoxylin. Whatever general statements are made are always in comparison with the nine controls, from which sections were also cut and similarly stained.

The cells generally in the Bridgman cortex have abundant pigment—the nuclei often somewhat irregular and the nucleoli sometimes single and clear, often multiple and unclear, and, at times, wanting. Where the cortical granules form layers they appear abundant, as a rule, and immature (i. e., without

angles), as though they had been arrested in their growth. The general impression one gets is, that the large nerve cells are neither so large nor so numerous as in the normal brains. Of cell processes and abundance of fibres one can only say, that there appear less of both in all localities, and hasten to add, that the poor condition of the material makes itself painfully felt at this point.

It seemed worth while, however, to select sections from several localities, especially those in which the cortex of the Bridgman brain appeared thin, and attempt to get some notion of the development of the cell elements at these points.

To arrive at this result I counted the number of cells above a given diameter in a strip of the cortex, comparing the number found in the Bridgman cortex with that in two controls. For results see Table X.

TABLE X.

To show the average number of cells 12 μ in transverse diameter which occur in 0.01 □ mm. of cerebral cortex at the localities named. Sections .02 mm. thick.

	MALE.			FEMALE.					
	Control III.			Control XI.			Laura Bridgman.		
Locality.	* R.	† L.	Aver.	R.	L.	Aver.	R.	L.	Aver.
Speech, 2	.85	1.10	0.975	1.06	1.16	1.11	.93	.80	0.865
Insula, 3	1.15	1.04	1.10	1.15	1.03	1.09	1.00	1.07	1.035
Head and Eyes, 4	1.13	1.40	1.26	1.03	1.46	1.25	1.11	1.19	1.15
Hearing, 6	1.23	.99	1.11	1.23	1.21	1.225	.81 c	.92	0.865
Taste and Smell, 10	.82	1.12	0.97	1.34	.97	1.155	.86	1.05	0.955
Sight, 11	1.03	.99	1.01	1.08	.95	1.015	.47 c	1.01	0.74
Sight, 14	1.13	1.08	1.105	.99	1.08	1.03	.40 c	.92	0.66
Average,			1.075			1.125			0.895

* R. = Right hemisphere.
† L. = Left hemisphere.

To obtain these figures the following method was employed. The specimen was fixed upon a mechanical stage in such a way that the direction of motion was vertical to the cortex. It was examined with a Zeiss apochromatic objective, 4 mm. focus, combined with the compensating eye-piece 6, tube 160 mm., thus giving an enlargement of 375 diameters.

The eye-piece carried the micrometer with 50 divisions. With the objective used, each division had a value of 4 μ. The whole scale covered therefore 50 times .004 mm. = .2 mm.

Placing the micrometer scale so that it was at right angles to the direction of motion for the specimen, and passing the specimen in review by means of the mechanical stage, a strip of cortex .2 mm. wide could be brought, throughout its entire extent, under the scale. In this manner the nerve cells were sifted, so to speak, through the micrometer scale, and each one that was 12 μ or more in diameter was picked out and counted.

In selecting the point on the section at which to make this test I always took the spot where the cells were apparently—to a low power—most abundant, and in all cases everything in the field that could be counted was counted.

The depth of the cortex where the count was made was multiplied by the constant width, .2 mm., and the total number of cells divided by this product, using .01 sq. mm. as the unit. The thickness of the section was always .02 mm., which being a constant factor may be neglected. By this treatment it comes out that about one cell, 12 μ or more in basal diameter, normally occurs in each .01 sq. mm. of a section .02 mm. thick.

For comparison with the Bridgman sections I took those from Control III. (Brain weight 1,393 gr., male, average thickness of cortex R. H. 2.77 m., L. H. 2.86 m.), and Control XI. (Brain weight 1,196 gr., female, average thickness of cortex R. H. 2.74 m., L. H. 2.74 m.), (see Table IV.), thus happening to get both the male and female with the thinnest cortex.

Table X. shows that, taking the average of both sides, at no locality in the Bridgman brain are the large nerve cells, as abundant as in the controls. The number in both the controls is nearly the same.

Taking the matter more in detail the motor areas in Laura do not show as great a poverty of large cells as the sensory areas.

In three instances (marked c in Table X.), the abundance of cells accords with the thickness of the cortex—i. e., the thicker cortex has the larger number of cells. These instances include the ones in which the Bridgman cortex most clearly deviates from the normals.

As in the measurements of cortical thickness, so in the abundance of cells, the Bridgman brain is clearly deficient at 6, the auditory area and in the right hemisphere at 11 and 14, visual area, while in the left hemisphere some deficiency is to be noted only at 14, thus again bringing out the contrast between the occipital regions on the two sides. Locality 10 has fewer cells than the controls, but the difference is not so marked as in the thickness of the cortex.

In general it may be added that where the number of cells above 12 μ. in basal diameter was small, that there the absolute number of large cells appeared smaller, and the very largest cells not so large, as in the controls. In other words, small number and small size of large cells appeared to be associated, though I have no figures to present on the point. If, however, my impression is correct, then Table X. only in part represents the difference in the development of the cortical cells of Laura as compared with the controls.

SUMMARY.

I.—General.

1. No figures can be given for the average thickness of the fresh normal cortex. The various investigators differ widely in their results. My own results agree most closely with those of Jensen.

2. Persons with an acquired defect of the central nervous system have a thinner cortex than normal persons.

3. Females have a slightly thinner cortex than males. Difference less than 1%.

4. The right hemisphere (normally) has a cortex a few per cent less thick than the left. Maximum difference 7%.

II.—Special.

1. The cortex of Laura Bridgman was abnormally thin, having but 89% of the thickness of the controls. If we suppose that in its other dimensions the cortex was similarly reduced in development, i. e. by 11% in each linear measurement, then its normal extent would have been 246,808 sq. mm. instead of 200,202.5 sq. mm. as found. This estimate is similar to some of those by the Italian observers, Calori ([46]) and De Regibus ([17-p. 276]).

2. The right hemisphere had on the average the thinner cortex—specially to be associated with the defective visual area.

3. The thinning in the motor areas was not so well marked as in the areas for the defective senses.

4. Cortex of motor speech centre was not thin.

5. Cortex of area for dermal sensations was well developed.

6. Auditory areas (6) on both sides and visual area on right side (11, 8, 14) remarkably thin.

7. Area for taste and smell (10) thin—associated with the generally undeveloped state of the temporal lobe.

III.—Histological.

1. The cortex of Laura Bridgman contained an abnormally small number of large nerve cells—i. e., cells 12 μ. or more in transverse basal diameter.

2. There were fewer nerve cells in the samples from the right, than in those from the left hemisphere.

3. The deficiency of nerve cells was not so well marked in the motor as in the sensory areas.

4. In the centre for motor speech (2) the number of nerve cells was abnormally small.

5. Number of nerve cells very small in the auditory areas (6), both sides, and in the visual area (11, 8, 14) on the right side.

6. Some diminution in the number of cells at (10), area for taste and smell. Region generally undeveloped.

7. The small number of cells was associated with small size of the largest cells.

The persistence of vision, though in a very defective form, is still of great importance to the full development of the visual cortex—e. g., right eye and left visual area in Laura.

Observations on the Olfactory Region.

Albert C. Getchell, M. D., Worcester.

Description of the Specimen.

The specimen submitted for examination was a portion of the ethmoid bone, extending from the anterior base of the crista galli to the sphenoid bone, a small part of the sphenoid being included in it. It contained nearly all the perpendicular plate of the ethmoid. At the sphenoidal end the lateral surfaces were devoid of mucous membrane; towards the frontal end the surfaces were quite covered with the remains of membrane in a ragged condition. The right superior turbinated bone presented a smooth surface marked with grooves. Between it and the perpendicular plate was mucous membrane. Little of the left superior turbinated bone remained, and that which did was rough and without grooves. The entire specimen measured from the extreme frontal to the sphenoidal end, 3 cm.; from the apex of the crista to the farthest point on the perpendicular plate, 2.2 cm.; laterally its greatest measurement was through the horizontal plate of the ethmoid, .5 cm. This line represented the base of two triangles; the apex of one being the tip of the crista, that of the other the farthest point on the perpendicular plate of the ethmoid.

The specimen had been hardened in Müller's fluid, and decalcified in a saturated solution of picric acid, the process being completed in a 1% solution of hydrochloric acid. It was imbedded in celloidin, and most of the sections were stained with Delafield's hæmatoxylin and eosine. Four additional stains were used for nerves, viz.: Upson's carminic acid, Schæfer's nigrosine, hæmatoxylin und carminic acid, and Pal's hæmatoxylin.

Results of the Microscopic Examination.

For the purpose of comparison, I obtained a specimen

similar to the one under consideration. This was a portion of the ethmoid bone taken from an elderly man who had been a patient at the Worcester Insane Asylum, and had died there. The presumption would be that this specimen could not be taken as a type of the normal, for it is difficult to suppose that one could pass the greater part of a long life in this climate without having had more or less nasal catarrh. The specimen was, however, healthy in its gross appearance: that is, it was symmetrical, both superior turbinated bones were present; their surfaces were shiny and grooved; the mucous membrane was generally and uniformly distributed between the perpendicular plate and the superior turbinated bones. The next point to consider was its microscopic appearance, and here arose the question, What is our standard for the normal? The work in this region has been done mainly upon the lower animals, and while the results obtained are in the main applicable to the olfactory region of the higher animals, including man, obviously it would be of great assistance to have well-conducted studies upon the olfactory region of man. In an investigation upon the olfactory region of a case of leukæmia Hermann Suchannek([84]) has touched upon this topic. He has figured a microscopic section of the olfactory region of a man 40 years old, with a normal sense of smell. The picture agrees with the usual description of this region. It represents a section consisting of a regular row of epithelial cells, resting upon a basement membrane, beneath which are many Bowman's glands, a few blood vessels and nerves, with little intertubular connective tissue. Unfortunately no measurements are given, either of the entire mucous membrane or the epithelium. My specimen presented a different appearance. The epithelial layer preserved for the most part its normal characteristics of a regular row of columnar cells resting upon a row of round cells, the epithelial cells being well formed and distinct. In many places, however, the surface was not so well defined, but was breaking into crowded irregular masses of granular matter, while the subjacent layer of round cells had disappeared, and its place was taken by a mass of round cells, which penetrated deeply the underlying tissue. In these localities the surface layer of cells was thrown

into folds which projected above the surface, and also ramified into the mucous membrane, like glands. There was a general increase of connective tissue. The thickness of the entire mucous membrane varied from .16 mm. to .88 mm. Those localities that measured .16 mm., taking as a standard the usual description and the figure of Suchannek, were fairly normal. The epithelium of these regions was particularly healthy. The epithelial layer varied from 30μ to 98μ in thickness (Kölliker quoted by Schwalbe(85) gives 40μ to 98μ as the normal thickness). It was thinnest at the extreme vault of the olfactory fissure.

In the Bridgman sections the thickness of the mucous membrane entire varied from .16 mm. to .64 mm., and the thickness of the epithelial layer from 48μ to 90μ. Taking .16 mm. as the thickness of the normal mucous membrane, I found those areas of the mucous membrane that were of this thickness, far from normal. The surface of the epithelial layer was covered with thin granular matter, and the surface line was very irregular. The cells took the stain poorly, showing that they were degenerating into mucus. In many places the cell bodies had entirely disappeared, leaving a mere outline of their former structures. The row of round cells had disappeared and its place was taken by a mass of cells, now pushing up into the epithelial layer, now invading the membrana limitans. In the sub-epithelial tissue there was a dense deposit of connective tissue. In no part of the specimen was the epithelium healthy. At some points the mucous membrane was entirely devoid of epithelial cells; at others, there was the row of round cells, now single, now two or three deep. In some places these cells were becoming polygonal in shape; again over them was a crowded confused mass of irregular cells breaking away. In some places there were breaks of continuity in the line of epithelial cells, otherwise fairly regular in their size and distribution. There were also places where the surface of the mucous membrane was thrown into elevations. There was generally a large increase of connective tissue, which, in some areas, had replaced everything else. In other areas was abundant infiltration of small, round cells. Bowman's glands were very irregularly distributed and varied

much in their character. They presented all gradations from a ring of fairly healthy polygonal cells to a confused mass of granular matter.

The mucous membrane on the right of the septum was much healthier than that on the left. Its thickness was uniform, though in some places there was an increased deposit of connective tissue. The curve into the vault of the olfactory fissure was uninterrupted and regular throughout this side of the specimen. The epithelial cells, though individually undergoing degeneration, were fairly regular in outline. Bowman's glands were numerous in the frontal part of the specimen, but toward the sphenoidal end they had disappeared. Throughout this area were nerves and blood-vessels, with greatly thickened walls. The left side of the specimen presented a very different picture. In the frontal fifth of the olfactory fissure was crowded a mass of connective tissue, in which were nerves, blood-vessels, glands, covered ventrad with degenerated epithelium. Still ventrad to this, the perpendicular plate was devoid of mucous membrane, as was also that part of the superior turbinated bone which remained; the greater part of this bone was either in small fragments or had entirely disappeared. The remaining four-fifths of this side of the specimen was occupied by a fibrous tumor, which was, as it were, in a closed cavity, the mucous membrane of the septum having firmly united with that of the superior turbinated bone, giving in the sections the appearance of a ring lined with epithelium, enclosing the tumor. The tumor sprang from the septum and projected into the superior meatus. Its length from its frontal to its sphenoidal end, estimated by the number of sections in which it was found, was upwards of 1.5 cm. It was irregularly polygonal in shape, and measured at its frontal end 1.12 mm. in height (that is, from the septum to the apex of the tumor) and 1.05 mm. in breadth, while at its sphenoidal end the corresponding measurements were 2.50 mm. and 1.44 mm. Its character changed from the frontal to the sphenoidal end. In the frontal region it was made up of a central column of dense connective tissue, which supported nerves, blood vessels, Bowman's glands, the whole being covered with a layer of epithelium as healthy as that in any part

of the specimen. At the sphenoidal end the central column was divided by a fissure, Bowman's glands had disappeared, and the whole tumor was filled with spaces of irregular shape, many of them full of blood corpuscles. Blood vessels remained, but there were few nerves and the greater part of the tumor was devoid of epithelium.

The Nerves.

There were two varieties of nerves in the specimen, a branch of the ophthalmic division of the fifth which passes into the nose through the fissure at the base of the crista galli, and the olfactory nerves. The branch of the fifth, a medullated nerve, was in the main normal. The axis cylinders stood out sharply throughout the greater part of the sections. In some areas, however, they had lost this distinctness and showed signs of beginning degeneration. But the change was no greater than might be expected in a woman of Laura's age.

Before entering upon the description of the olfactory nerves of this specimen, it will be well to discuss briefly the normal and pathological anatomy of the olfactory nerve in general.

The generally accepted view of the non-medullated nerve, of which the olfactory is a type, is that it is made up of the so-called Remak's fibres. Each of these consists of an axis cylinder, a neurilemma, and between the two a nucleated nerve corpuscle from place to place. This fibre has a striated appearance due, according to Max Schultze, to the fibrillæ of the nerve, which are distinguished from the axis cylinders of a medullated nerve in that they individually have no medullary sheath. Boveri$_{(86)}$, on the other hand, has made a careful study of this subject, and concludes that the fibrillæ of Max Schultze are really nerve fibres, each having a medullated sheath. This sheath does not, however, belong exclusively to each nerve. It sustains the same relation to the contiguous nerve fibres that the cell wall of a honey-comb does to the cells. A number of these nerves are surrounded by an envelope of connective tissue, in which are here and there stellate connective tissue corpuscles. There are also within the investing sheath, among the nerves, connective

tissue corpuscles, with stellate rays which can be traced very far, even to the enclosing sheath.

The olfactory nerves are subject to certain definite pathological conditions. In the first place, they may be congenitally absent. Injury to the head may cause rupture to the nerves as they pass through the cribriform plate. Excessive stimulation may temporarily or permanently destroy their excitability. Tumors in the brain or cerebral hemorrhage may by pressure cause disease of the olfactory nerves. There may be atrophy of the bulb or nerves, or they may be affected by the degenerative changes of old age. Simple neuritis is a very rare affection (Althaus) ([87]). Chronic neuritis, due to syphilis, however, is not uncommon. The nerve may become involved in local inflammatory changes in connection with meningitis. Bosworth([88]) is of the opinion that a very frequent cause of anosmia from diseases of the olfactory nerves is due to the influence of local inflammatory changes. Thus in acute rhinitis, anosmia persists many days after the inflammatory process undergoes resolution. In severer disease of the nose, where the local inflammatory action persists longer, or is of a severer type, the anosmia lasts much longer, long after the inflammatory action has subsided.

To return to our specimen. The nerves were numerous and were easily distinguished by moderate powers of the microscope (320 diameters.) To get some definite idea of the distribution of the nerves in the different parts of the specimen I selected five slides and counted the nerves on them. One of these sections was from the frontal end, one from the sphenoidal, the other three at regular intervals between them. I also made a count of the nerves of the control specimen under similar conditions, with the following results, (The slide numbered one in each case, was from the frontal end).

Bridgman.			Control.		
1st slide,	1	nerve.	1st slide,	4	nerves.
2nd "	7	"	2nd "	20	"
3rd "	28	"	3rd "	10	"
4th "	32	"	4th "	8	"
5th "	18	"	5th "	15	"
	Total 86			Total 57	

This enumeration is of interest in that it shows the distribution of the nerves in the different parts of the specimens, but it gives no reliable information as to the relative number of nerves in the two specimens. It is a difficult matter, even under favorable conditions, to stain the olfactory nerves so as to show the nerve fibres. In neither of these specimens was I able to show the olfactory nerves with the special stains for nerve tissue. The only stain that brought them out at all was the hæmatoxylin and eosine, which did it by virtue of its differentiating the connective tissue. We shall see that this latter was greatly increased in the Bridgman specimen, and it is evident that because of this many more nerves would be detected than in the healthier specimen.

In the Bridgman slides, the nerves were surrounded by a ring of connective tissue which was very thick. Within this ring was a uniformly granular field broken up into smaller areas, and more or less studded with deeply stained dots. With a $\frac{1}{12}$ oil immersion objective, these dots were seen to be stellate connective tissue corpuscles. The areas alluded to above corresponded to the portions of the nerve bounded by the connective tissue envelope in Boveri's sections. Here, as with his sections, the connective tissue corpuscles were upon and within the sheaths. Rather the connective tissue corpuscles of the sheath were where the sheath should be, that place being represented in our sections by a vacant space. As this apparent shrinking was quite general throughout the specimen, I attributed it to the action of reagents. With this power, the nerve presented a regularly mottled appearance, very similar to a section of a frog's olfactory nerve as figured by Boveri, and representing according to his views the cut ends of the nerve fibres. The nerve in its essential elements, therefore, was normal. The connective tissue elements, however, were largely increased.

General Considerations.

It will be interesting now, to gather together the available facts relating to Laura's sense of smell, and the general condition of her nasal mucous membrane during life, and to find, if we can, in the condition of this membrane an explanation of her symptoms.

As an infant she was delicate, being subject to severe convulsions. But later her health improved, and when two years old she is described as being more active and intelligent than ordinary children. At two she had scarlet fever with such severity that for seven weeks she was unable to swallow solid food. Both eyes and ears were affected, suppurating freely ([1–p 2]). When seven years old she was seen by Dr. R. D. Mussey, Professor of Anatomy and Surgery at Dartmouth College, and in a letter dated April 14, 1837, he thus alludes to her sense of smell: "Her sense of smell is thought by her mother to be less acute than other children, as she very seldom applies any odorous substance to her nose: it is not improbable that this sense may have been impaired by the fever"([1–VIII]). In this year, 1837, she entered the Perkins Institution and we find in Dr. Howe's report this note ([2-155]): "For all purposes of use she is without smell, and takes no notice of the odor of a rose, or the smell of cologne water, when held quite near her, though acrid and pungent odors seem to affect the olfactory nerve." April 6, 1842, Miss Swift, Laura's teacher, made this note([1–p. 107]): "Dr. Howe came into the room, while she was having a lesson, peeling an orange. She stopped in the midst of a sentence to say, 'I smell an orange.' We can see a decided improvement in her sense of smell since last year, but she has never noticed any perfume so quickly or at so great a distance before." June 19, 1844, we find this note([1–p. 257]): "This is the first season she has ever perceived the smell of a rose or pink, and she now puts all flowers to her nose and is disappointed if they have no perfume. In a letter to Mrs. Howe, dated June 25, 1844, Laura herself says([1–p. 258]), "I can smell roses much better than I did two years ago, and it gives me much pleasure in smelling roses."

I find but few observations upon the general condition of her nose. Dec. 14, 1843, Miss Swift made this note([1–p. 215]): "She has always been a sufferer from a severe catarrhal affection, and as this shows signs of improvement, we hope for a corresponding one in both smell and taste." In 1878 Dr. G. Stanley Hall, in the course of a series of observations upon her several faculties, examined her nose with this result([6]):

"There is no deformity or scarification observable without or from a cursory examination within the nose, and the yellow pigment of the Schneiderian membrane can be seen by a very simple apparatus." Dr. Hall made further this very interesting observation. He described her sleeping with long regular breathing, the teeth slightly apart and the tongue pressed against them and almost between them.

I have received the following letter from Miss Della Bennett, who has been a teacher in the Perkins Institution since 1876:

"Laura Bridgman lived for several years in the same family with myself, and I have conferred with the matron of the cottage, and can answer most of your questions definitely. There was copious discharge from her nose, so much so that she was wont to say, 'My poor nose!' Her handkerchief was in frequent demand, and she used many. Her breath was never offensive. She always breathed through her nose, a habit which she formed when quite young, and her breathing was often accompanied with a gentle whistling sound. I have seen her asleep in the daytime and her mouth was closed, but I cannot tell about the night. She did remove mucus from her throat, and occasionally had a sore throat."

From these notes one gathers that at the age of two, Laura suffered from a severe inflammation of the naso-pharynx, which doubtless extended to her nose: that after her illness she was quite destitute of the sense of smell, entirely so when at the age of eight she entered the Perkins Institution: that at the age of fifteen she could detect with certainty and pleasure moderately pronounced odors: that she had a severe nasal catarrh which lasted her entire life, although it decreased somewhat in severity: furthermore that there was no deformity without or within the nose that could be seen by one not accustomed to examine these parts.

We now come to the consideration of the cause of Laura's anosmia and her partial recovery from it. We have seen that the olfactory nerves were capable of performing their function, and according to Dr. Donaldson (*vide ante*) there was no central lesion that would cause anosmia. We must therefore seek for the cause in the periphery of the nervous

apparatus. The two chief peripheral causes of anosmia are obstruction to the inspired air due to deformity of the nose, hypertrophy of the turbinated bodies, nasal polypi or tumors, and atrophic disease. That there was not atrophic disease is shown by the absence of bad odor, by the partial return of the sense of smell, and by the result of our examination of the specimen. Furthermore, according to Bosworth, catarrhal affections caused by febrile diseases and prominently scarlet fever, are characterized by hypertrophic changes ([88—p. 157]). It is quite improbable that Laura had any deformity of the nose or hypertrophic disease in the respiratory part of the nose, which would interfere very materially with the access of the inspired air to the olfactory region, and it is in this latter region, therefore, that we must look for the cause of her anosmia. We have found in the left superior meatus an adequate cause for a complete absence of the sense of smell for that area, in the extensive disease there which resulted in a thorough disorganization of the mucous membrane in a part of the olfactory fissure, while the rest was excluded from all contact with the inspired air by the firm union of the mucous membrane of the septum with that of the left superior turbinated body. In the right superior meatus, on the other hand, conditions were more favorable for the proper performance of function. It is here that Laura must have smelled, and the questions now to be settled are, how could this area have been rendered incapable of performing its function, and how could this function have been resumed.

Catarrhal inflammation of the nasal mucous membrane is the usual accompaniment of scarlet fever, except in the mildest cases, and is associated with an irritating discharge from the nose (Smith)([89]). The inflammatory process in these cases does not involve more than the epithelial layers. But in severe disease the deeper tissues of the mucous membrane are affected. There is a copious proliferation of cells in the deeper layers, with fibrinous infiltration even to the extent of compressing the vessels and making portions of the tissue gangrenous (Henock)([90]). There may even result necrosis of the bones (Thomas)([91]). There may be recovery even though the disease be severe, or it may result in chronic disease with

more or less profuse discharge and extensive inflammatory infiltration, or there may be an osteitis of all the bones which enter into the composition of the nasal cavities (Allen)([92]).

That Laura's nasal mucous membrane was profoundly affected by the fever there seems no doubt, and it is easy to conceive how the active cell proliferation and swelling of the mucous membrane caused by the catarrhal process would have so affected the delicate termination of the olfactory nerves that they would be entirely incapable of functioning. But as time went on we know her catarrh grew better and we rightfully infer that the inflammatory processes in the mucous membrane subsided, to an extent, though they never entirely ceased. We have seen that the structures of the nose were a good deal damaged, yet they were not entirely useless. In the right superior meatus especially, there were spots of membrane in a fairly healthy condition. A question of interest here presents itself—would the olfactory nerves after so long a period of inactivity preserve their power of responding to stimuli? The following case reported by Allen ([92]) proves that this is possible. The patient was a married woman. She had never breathed through her nose and had never experienced the perception of an odor. There was found to be a complete bony occlusion of the posterior nares. This was broken through and on the sixth day after the operation she began to smell and in a short time became familiar with the common odors and flavors. The odoriferous air was not kept from Laura's olfactory nerves by bony obstruction, but it was kept from them by what acted as efficiently for a long time, namely, masses of rapidly proliferating cells, and the mucus and débris of a diseased mucous membrane. When this process subsided it again became possible, in those areas where the ephithelium still remained sufficiently healthy, as it did in places, for the terminal filaments of the nerves to receive and convey their proper stimuli. There may have been a further cause for the anosmia. When discussing the pathology of the olfactory nerve, we alluded to Bosworth's view that anosmia was due in some cases to the local action of the surrounding inflammation upon the nerve itself. As I understand the matter he bases this view solely upon clinical experience, and attempts no explanation of the tardy return of the sense of

smell after the subsidence of the inflammation. We have in our sections a possible explanation of this peculiarity. The connective tissue of the nerve was increased in amount, while the nerve tissue proper was apparently normal. Interesting questions suggest themselves in this connection. Does the development of this tissue impair the functioning power of the nerve, and does a nerve so affected resume its normal activity more slowly than the surrounding tissue? At present, so far as I know, there is not sufficient anatomical data upon which one could even discuss these topics.

Summary.

I. The ethmoid bone and the mucous membrane covering it had suffered from inflammatory disease, which particularly affected the left side. 2. This disease resulted in an excessive production of connective tissue, and in one area, the left superior meatus, there had been formed a fibrous tumor. The epithelium was generally and considerably diseased. The nerves contained an excess of connective tissue, but were otherwise normal. 3. When two years old, Laura had scarlet fever, which left her anosmic and with severe nasal catarrh. She partially recovered from both these conditions. 4. The anosmia was due to the occlusion of the left olfactory area by the union of the mucous membrane of the septum with that of the superior turbinated body, and also to the action of the inflamed mucous membrane upon the nerves of the right olfactory region. Partial recovery resulted from subsidence of this inflammation.

II.—The Visual Apparatus.

When Laura recovered from her illness it appeared that she was totally blind in her left eye but could see somewhat with the right. The remnant of vision in her right eye continued up to the eigthth year of her life.

From that time on she was absolutely blind in both eyes.

In 1878 Dr. O. F. Wadsworth, of Boston, tested her for vision and found her totally blind ([6]) and at the same time reported on the appearance of the eyes as follows :

"On both sides the lids are sunken, partly on account of lack of the normal amount of orbital fatty tissue, partly on account of the small size of the eyeballs. They remain constantly closed. The right conjunctival sac is much smaller

than normal, somewhat irregular, and presents an appearance such as is seen after severe and long-continued inflammation. The right eye appears about one half the normal size. It is wholly enclosed by the sclerotic, except over a space at the centre, some two millimetres in diameter, where a less opaque tissue, on which a few blood-vessels are visible, represents the altered remnant of the cornea. The left conjuctival sac is somewhat larger than the right, and more regular, though still small. The left globe also is a little larger than the right, and its opaque altered cornea is some four millimetres in horizontal and two millimetres in vertical diameter. There was constant irregular oscillation of the globes [nystagmus] whenever they were exposed to view by raising the lids, and the oscillation evidently continued even after the lids were closed."

At the autopsy the eyes were removed with the surrounding tissue and put unopened into the Müller's fluid and alcohol. The hardening was completed in alcohol.

Both bulbs were enclosed by orbital fat. All the muscles the of bulbs were present, though small, and the external appearance of the bulbs corresponded with Dr. Wadsworth's description given in 1878. After hardening, the right eye had a transverse diameter of 15 mm. and an antero-posterior diameter of 10.5 mm. Similar measurements of the left eye gave 17.5 and 11. mm. showing the left to be decidedly the larger. The condition of phthisis bulbi existed for both eyes. There was a faint indication of the anterior chamber. The locality of lens and vitreous contained abundant calcareous deposits in small masses and the choroidal pigment was very abundant. Sections through the point of entrance of the optic nerve showed no trace of the retina or normal nervous elements at this point. Both eyes were similar in the appearance just mentioned. As has been stated the optic nerves were small :

Right optic nerve,	area of	cross-section	near	chiasma,		5.00	sq. mm.
Left	"	"	"	"	"	3.38	" "

The connective tissue was vastly increased in both nerves but one also saw the characteristic cross sections of axis-cylinders with their medullary sheaths. The fibres were both

large and small. It is worth noting that these fibres were abundant in the left nerve but much less so in the right, although the right was the larger nerve. The chiasma was much flattened dorso-ventrally. The optic tracts were small and flattened. Their area was taken about 10. mm. behind the chiasma. The relations of size were of course reversed at this point and the left tract was the larger:

Right optic tract near chiasma,	3.13 sq. mm.
Left " " " "	4.69 " "

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The Eustachian tube is impervious; its tympanic end being closed by bone and just beyond this there is an accumulation of cheesy matter also enclosed by bone. There are no air spaces within the tympanum for all the bone cells are filled with tissue, although in the highest part of the petrous bone there is a cell which connects with the tympanum. There is no evidence of mastoid cells or antrum. (I did not see the mastoid process).

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The floor of the osseous meatus is defective externally and is pierced internally and anteriorly by a foramen 1 mm. in diameter, in the fissure of Glacier.

External to the fibrous diaphragm there is a diaphragm formed by hyperostosis of the walls of the canal which obstructs the passage except near the centre and slightly external to the normal position of the membrana tympani, where there is an opening 2 x 4 mm.

The hyperostosis extends into the tympanum filling the greater part of it, but leaving a space external to the fenestræ and below the promontory, also a considerable space in the external anterior and superior part of the petrous bone.

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Before I saw the specimen the tympanum had been opened and some of its contents taken out; all of this was lost except the head and neck of the malleus with the base of the long process, all enclosed in fibrous tissue.

The relations of the fenestra ovalis and the attachment of the tensor tympani muscle had also been destroyed. The chorda tympani nerve was found intact. The tendon of the stapedius muscle was protruding from its tubercle.

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On comparison with a number of normal specimens the caudal pair of the quadrigemina exhibited no marked peculiarity. They were small, but no smaller than in the case of some normals. The corpora geniculata interna did not appear small in Laura upon gross examination but this appearance I am inclined to attribute to the failure of the surrounding regions to fully develop, thus causing the corp. gen. int. to stand out with unusual clearness.

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large and small. It is worth noting that these fibres were abundant in the left nerve but much less so in the right, although the right was the larger nerve. The chiasma was much flattened dorso-ventrally. The optic tracts were small and flattened. Their area was taken about 10. mm. behind the chiasma. The relations of size were of course reversed at this point and the left tract was the larger:

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region in the case of Laura. At present then I look on the slenderness of this gyrus, especially on the right side, where the cortex is most affected, as an expression of the incomplete development of the region. Mills (42, 68), Starr (41), Manouvrier (83).

At first sight the small disturbance—to the naked eye at least—existing between the middle ear and the cortex is striking. Histological investigation up to the centres in the medulla yields a similar negative result. Between the medulla and cortex the condition of the specimen did not warrant a histological study.

In the scattered literature relating to the examination of the ear and brain in deaf-mutes, a condition where there is little or no apparent abnormality of the inner ear, the auditory nerve or the medulla, associated with disease of the middle ear, deafness and (sometimes) atrophy of the cortical auditory centres, is occasionally described: Bremer (69), Larsen & Mygind (70), Moos (71), Mygind (72), Obersteiner (73), Moos and Steinbrügge (74, 75, 76). I believe that in future cases, like that of Laura, a more detailed examination than it was possible to make in her case will show disease of the membraneous cochlea or the nerves between it and the spiral ganglion of the cochlea. Such a case has been reported by Moos and Steinbrügge (79).

As long, of course, as the cells of the spiral ganglion are intact, just so long will the auditory fibres associated with them—and this must represent a very large portion of the cochlear division of the auditory—remain morphologically intact. Following the pathway to the cortex we find no point at which marked changes occur until we reach the cortex itself. The disturbance here is most probably due to the early and long continued lack of normal excitation, for the cortical cells in the sensory areas are peculiarly dependent for their proper development on the special sense with which they are associated.

The evidence from stimulation of the cortex and from the histology of the medulla goes to show that the association between the auditory nerve and the cortical centre for hearing is to some extent at least, a crossed one. If this were so, then

the smaller, left nerve, would associate itself with the thinner, right cortex. This relation exists in the case of Laura, but it remains for further investigation to show its significance. Strümpell ([78]).

As regards the semicircular canals it may be added that they were not found diseased. Their nerve was in good condition, and sensibility to rotation, sense of direction, etc., were present. Of course the relation of this part of the inner ear to the middle ear is less intimate than that of the cochlea, and this in part may account for the normal preservation of the canals. That both portions of the labyrinth need not be conjointly affected is shown by James ([79]), in his study of the sense of dizziness in deaf-mutes, where this sense was found totally lacking in only 186 out of the 519 cases examined.

IV.—The Cranial Nerves.

It is desirable to bring together the various facts regarding the cranial nerves in Laura's case: After what has been said in the foregoing pages, and the discussion of their area by Mr. Bolton and myself ([vide p. 234]), this can be briefly done. Table XI. gives the various points in a condensed form.

TABLE XI.

Nerve.		Area in sq. mm.	Condition.	Size.
I. Olfactory, bulb,	right	6.34	Somewhat atrophiad	Small
" " tract,	right	1.46	" "	"
II. Optic nerve,	right	5.00	Greatly atrophied	Very small
" " "	left	3.38	" "	" "
" " tract,	right	3.13	" "	" "
" " "	left	4.69	" "	" "
III. Oculomotor,	right	3.17	Normal	Large
" "	left	3.51	"	"
VIII. Auditory,	right	4.26	Somewhat atrophied	Small
" "	left	3.17	" "	"

The sixth nerve—abducens—contained only normal fibres and appeared healthy, but the measurements on the two sides were so different that I suspect some strands were lost, and hence do not give the figures for the area.

The only nerve in the Table which has not been discussed is the olfactory. The bulb was flattened and the glomeruli could not be identified. The ganglion cell layer was there, and contained some well formed cells. The other layers were poorly preserved. The vessel walls were thickened. There was some excess of connective tissue and an abundance of

hyaline bodies—corpora amylacea (?). Distinctly degenerated fibres could not be made out in the tract, but the vessels, connective tissue, corpora amylacea, were found as in the bulb. Grossly the left tract and bulbs were like the right, but by accident the former was lost before it had been examined histologically.

Whether there was anything peculiar in the glossopharyngeal fibres I am unable to say. The portion within the medulla was normal.

The medulla which was examined from the level of the pyramid to the middle of the pons, by means of sections, showed no abnormality save in the neighborhood of the accessory nucleus of the auditory nerve, where the cells appeared small, reduced in numbers and highly pigmented.

The pia of the hemispheres had a normal abundance of nuclei in it, even over the occipital region—and the blood vessels were normal in size and thickness of their walls. The cerebellum was also normal.

V.— Conclusion.

From these fragmentary observations, which leave so many points connected with this special case still undecided, it will be advantageous to construct some sort of general picture.

The anatomical condition was that of a normal brain in which the olfactory bulbs and nerves, the optic nerves, the auditory nerves, and possibly the glossopharyngeal, had all been more or less destroyed at their peripheral ends. This destruction caused a degeneration—most marked in the optic nerves—which extended towards the centres and involved them indirectly. This condition has left its mark more or less plainly on the whole brain, as indicated by the extent and thickness of the cerebral cortex, and specially by the cortex connected with these deficient sensory nerves. The physiological effect of the peripheral lesions, as I conceive it, was to retard growth in the centres, cortical and subcortical, which were thus involved, and also to interfere with, if not entirely prevent, the formation of the association tracts.

To be sure this case represents a maximum loss in these defective senses with a minimum amount of central disturbance, thus offering the very best sort of opportunity for education by way of the surviving senses. At the same time, we must

imagine the hemispheres to have been traversed in every direction by partly or completely closed pathways. The brain was simpler than that of a normal person, and Laura was shut off from those cross-references between her several senses, which usually so facilitate the acquisition of information and the process of thought. Mental association was for her limited to various phases of the dermal sensations and the minor and imperfect senses of taste and smell. Yet from their fundamental and protean character, the dermal senses are perhaps the only ones on which alone the intellect could have lived. We are thus brought back to Sanford's (7) conclusion as derived from the study of her writings. "She was eccentric, not defective. She lacked certain data of thought, but not, in a very marked way, the power to use what data she had."

One word more upon the cortex. The deficiency in the motor speech centre is mainly macroscopic, as far as the third frontal gyrus is concerned. The motor centre there had lost some, but not all its associative connections. Histologically, it was slightly deficient. The lesion there was so different from that of the sensory centres that a histological difference ought not, perhaps, to be surprising. The cortex of the sensory centres was not sunken below the surrounding level, though the gyri were slender and flattened. Possibly in this sinking in a motor area and the absence of the same in the sensory areas, we have a suggestive difference in the reactions of the several portions of the cortex.

Finally, the deficiency was not so very great even in those areas, where it was most marked, and the question arises as to what sort of occupation the cells in those areas had, which would thus justify their prolonged existence. If they were thrown entirely out of function it is not easy to see how they could last so well for nearly sixty years. In some way then they may have taken a slight part in the cerebral activity, but it was so slight that their specific reactions did not rise into consciousness, for though Laura had some light perception up to her eighth year, she apparently had no visual memories, whereas those who have retained full vision up to four and a half or five years of age and then become blind, do usually remember in terms of sight (8).

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CORRIGENDA. I. ARTICLE.

Page 304. The percentage increase in volume is certainly too large. It should be one or two per cent. less than that for weight.

Page 306. Line 8. All the specimens mentioned in this paragraph except the Bridgman, are supposed to have been weighed with the pia on. To make this specimen comparable then its weight must be increased by the weight of the pia, 31.4 grms. This makes the total weight of the Bridgman encephalon, with pia, 1235.4 grms.

Page 312. Line 13. Topinard's Table (Éléments d'Anthropologie générale, Paris, 1885) in his Anthropology, p. 518 shows the relations between brain weight and age. It is based on 1913 cases of Boyd, and according to it the maximum encephalic weight for females, falls between the ages of 20-30 years; that for males between 30-40 years; This indicates brain growth up to the age of maximum weight, therefore beyond the twenty-fifth year.

Page 324. Table. The first series of weights stands under the heading "Weight of cerebral hemispheres, fresh." The question arises whether "cerebral hemisphere" should not be replaced by "encephala." I have not seen any account of how much of the encephalon was used in determining the fresh weights in this series, but, since these brains were directly compared with those of other observers in which the entire encephalon had been weighed, it is only fair to suppose that they had been treated in the same way. This was my opinion until I found a table in R. Wagner's(31) Vorstudien, 2te Abhandlung, 1862, P. 91, in which the weights of the two "hemispheres," of at least three of these brains in the table, are compared with one another. The specimens had been in alcohol the strength of which is not given. Now the sum of the weights of the two "hemispheres" is nearly equal to or more than the weight of the "brains" given by H. Wagner (44) 1864. I therefore used the word "hemisphere" in the above heading as equivalent to hemicerebrum. It would appear that both the Wagners used it as equal to hemiencephalon. In the above mentioned table then the weights given are these for the entire encephalon and not for the cerebrum only.

Page 328.	Table I.	*For* absolute difference,	1398.4	sq. mm.
		Read " "	1598.4	" "
		For in percentage,	1.8%	
		Read "	1.9%	
Page 334.	Table VIII.	*For* total (left),	101256.0	sq. mm.
		Read " "	101255.2	" "
		For absolute difference,	2309.5	" "
		Read " "	2308.7	" "

PLATE III.

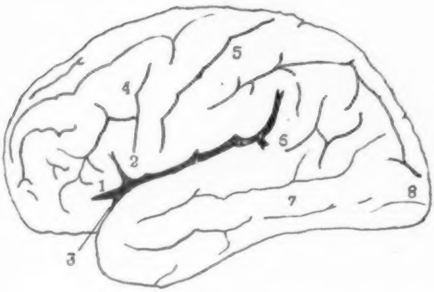


FIG. 1. Lateral aspect. 3 is used to designate the insula here not exposed.

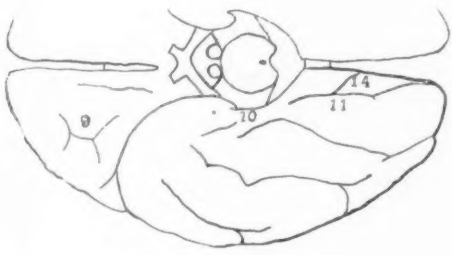


FIG. 2. Ventral aspect.

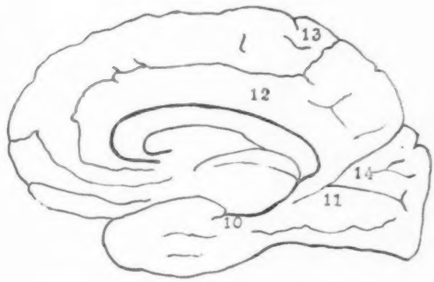
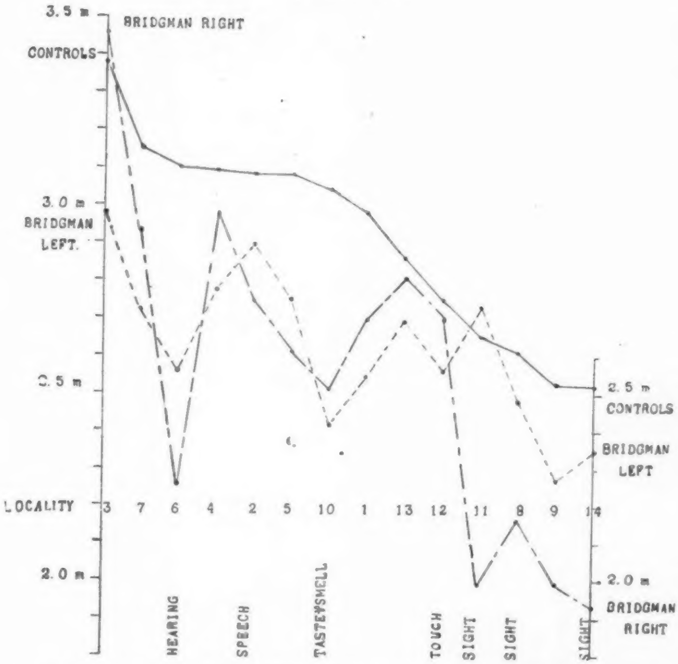


FIG. 3. Mesal aspect.

Explanation of Plate III. This plate shows the localities on the hemispheres from which the samples of cortex were taken. For the physiological value of these localities Table III may be consulted.

Plate IV.



Explanation of Plate IV. The curve was originally plotted so that the thickness of the cortex was magnified 100 times, i. e., .01 mm. of cortex corresponded to 1. mm. on the ordinates. The original has been reduced for printing to somewhat less than six-tenths of its linear scale. The figures placed by the ordinates indicate the thickness of cortex. The summits of the curves are alone represented, there being 1.8 mm. of cortex below what is shown. The figures for the localities cross the plate in a horizontal line, with the important designations below them.

The curve for all controls is in a solid line, ———
The curve for L. B., right hemisphere, is in long and short dashes, — - —
The curve for L. B., left hemisphere, is in short dashes, - - - -

PSYCHOLOGICAL LITERATURE.

I.—NERVOUS SYSTEM.

Ueber das Verhältniss der experimentellen Atrophie und Degenerations-Methode zur Anatomie und Histologie des Centralnerven systems. Ursprung IX, X, und XII Hirnnerven. Dr. AUG. FOREL unter Mitwirkung von Dr. MAYSER und Dr. GANSER. Mit einer Tafel. SEPARAT-ABDRUCK AUS D. FESTSCHRIFT DES FÜNFZIGJÄHRIGEN. Doctor JUBILÄUM der Herrn Prof. Dr. KARL WILHELM von NÄGELI in München und Geheimrath Prof. Dr. ALBERT von KÖLLIKER in Würzburg. Zürich, 1889.

This paper explicitly contains nothing new. In his clear and emphatic way Forel sets forth the value of the method of experimental atrophy and degeneration, and shows the utter impotence of the view that a so-called anatomical problem is to be dealt with by means of traditional anatomical methods. Any method, or better, every method which is applicable must be employed, and only results which are obtainable by several methods have a right to be regarded as well established. The method of degeneration is illustrated by what it has contributed to our knowledge of the medullary centres of IX, X and XII nerves. To those who wish to know what the method of v. Gudden is and can do, and to those who are aweary with the much reading of sapless anatomy, this paper will be a delight.

Cerebral Localization. DAVID FERRIER, M. D. Croonian lectures—Lancet. June 7, 14, 21, 28, July 5, 12. 1890.

In these six lectures the author goes over the entire subject, laying special stress on the centres in man. For these lectures some new experiments have been specially made, and these are of particular interest from the bearing they have on Ferrier's own views.

The first lecture opens with an account of the comparative physiology of the cerebral hemispheres, in which the author draws largely on the work of Steiner, Schrader, Goltz and others. The reactions of the shark, bony-fish, frog, bird (pigeon), and mammals (rabbit and dog), are described, after more or less complete removal of the cerebral hemispheres. Following this is a brief historical account of the work on localization, in which Ferrier points out the unsatisfactory nature of the evidence for absolute and relative centres, as advocated by Exner, gives Beevor's figure for the relations of the fibre-bundles in the internal capsule—as derived from recent experiments on direct stimulation in that locality—and passes to the arguments in favor of the direct excitability of the cortical cells—the best of which are the tetanic response to single stimuli, and the longer time taken for reaction when the cortical cells are present.

The second lecture deals with the results of electrical stimulation of the cortex—mainly in monkeys—and diagrams of the localizations of Beevor and Horsley and others are given. Schäfer has reported movements of the eyes in monkeys which stand in a definite relation to the portion of the occipital lobes stimulated. Ferrier admits the general fact, but still contends that more precise movements can be gotten from the stimulation of the angular gyrus. After giving an account of the

results of stimulation of the cortex in man, the author alludes to the completeness with which centres may be separated. His position has been that of a complete separation, and although he does not abandon this view now, he nevertheless argues for the great difficulty of demonstrating it. In considering the visual centre, Ferrier sees in the experiments of Schäfer just mentioned and those on the latent period of excitation for this region a confirmation of his view that the motor reactions here obtained are reflexes from sensory stimulation. The evidence is by no means convincing. The visual area is the occipito-angular region. The relative values of the angular and occipital regions are by no means easy to determine, but Ferrier grants more significance to the occipital region than on previous occasions. It appears that injury to the occipital lobes causes crossed hemiopia, while injury to the angular gyrus produces blindness or amblyopia of the opposite eye. Destruction of both the angular gyrus and the occipital lobes is the only lesion which gives a permanent result. Brown and Schäfer's further investigations would appear to show that removal of the occipital lobes alone is capable of producing a complete and permanent blindness. Ferrier would explain this result by incidental injury to the angular gyri. For Ferrier the angular gyrus is the centre for central vision. As against Munk, he points out that no sensory disturbance—save the visual one—follows its removal, and that the gyrus has some slight connection with the eye of the same side. On reviewing the clinical evidence bearing on the visual centre, Ferrier does not find it to support the views of Seguin and Nothnagel—that the cuneus is the most important region in man, but would explain the connection between lesions of the cuneus and disturbances of vision by injury to the optic radiation thus brought about. In the discussions of the visual centres in the lower vertebrates Ferrier introduces an interesting experiment in which the physiological proof for partial decussation of the optic fibres in the owl is strong, though it has not yet been anatomically demonstrated.

In the fourth lecture he takes up the auditory centre. From his previous, as well as from fresh experiments to determine the centre for this sense, Ferrier concludes that the caudal portion of the superior temporal gyrus is the centre. Clinical evidence supports this view, but Schäfer opposes it on experimental grounds. At present the results appear irreconcilable. In discussing the location of this centre in dogs—where it occupies not the first but the second temporal gyrus—Ferrier takes occasion to suggest that what appears to be the first temporal gyrus in this animal is really the homolog of the insula in the higher forms. If this view be correct, then the position of the auditory centre is homologous in the primates and carnivora.

The centres for tactile sensibility are next discussed. As an introduction, the views concerning the paths in the spinal cord and some new experiments on monkeys are given, but all without establishing any positive conclusion. Ferrier's own observations on the disturbances of tactile sensibility after interference with the hippocampal gyrus and those of Horsley and Schäfer on similar disturbance from destruction of the gyrus fornicatus, are described in the opening of the fifth lecture, and he concludes that in the limbic lobe we have the centre for cutaneous sensibility. Thus far no evidence has been given for subdivisions of this centre, but it would appear that in each hemisphere it is connected with both sides of the body, though mainly with the opposite side.

For the olfactory and gustatory centres, both experimental and clinical evidence is scanty and the former contradictory. Relying mainly on his own experiments and the suggestions of comparative anatomy, Ferrier maintains that these centres are in hippocampal lobule and the tip of the temporal lobe.

In the sixth and last lecture the bilateral connections of certain cortical centres—such as those for the trunk—are discussed. It would appear that there is never any recovery of function due to the assumption of new functions by other parts of the cortex, but that the apparent restitution depends ultimately on this bilateral connection. It would further appear that the associated movements of limbs on opposite sides of the body are due to similar anatomical connections. The complete separateness of the motor areas and those for the dermal senses is maintained on the ground of both experimental and clinical evidence. The motor character of the cortical motor centres and their dependence on the surrounding sensory centres is emphasized. Of the function of that portion of the hemispheres lying in front of the praecentral sulcus little can be said, save that it is connected with fibres in the anterior portion of the internal capsule which degenerate downwards on its removal; that it passes over into the centres for the movements of the head and eyes, and that when it is removed both men and animals show some impairment of intelligence.

The So-called Motor Area of the Cortex. EDWARD B. LANE, M. D. American Journal of Insanity. April, 1891.

The author examines some of the evidence for the motor character of certain regions of the cortex. In pursuing this he discusses the muscle sense, aphasia in its various forms, and the very interesting cases of "motor hallucinations" described by Tamburini and Séglas. In these cases the patient detected the words which are spoken to them, or better through them, or which they are forced to speak (!) not through an auditory sensation, but by means of the "movements of their own tongue," to employ their expression. In the case of Tamburini the tongue could be seen to move at the tip, but when held motionless (?) the hallucinations still occurred. Further, while the patient is pronouncing one group of words she feels at the same time others forming in her mouth. The author concludes strongly in favor of the sensory nature of the so-called motor cortex.

In criticism of this general view a little anatomy will assist us. (Supposing that motor cells, or those giving rise to efferent impulses, exist predominantly in the motor regions, they must be started into action by impulses from the periphery—i. e., sensory impulses. One question is then whether these sensory impulses reaching the motor cortex by sensory fibres there find sensory, or better central, cells with which they connect and by way of which they act on the motor cells, or whether the sensory fibres act directly on the motor cells. Histology does not enable us to decide the point, though pending a decision the latter view has been generally accepted. That the motor region contains a very large number of cells that carry efferent impulses from the cortex, we know from the make up of the internal capsule, and the pyramidal tracts, and the question here is, whether these peripherally discharging cells have some sensory function. This has been usually answered in the negative. We do not say that these usual views are correct, but think that the detailed anatomy of the cortex as well as the clinical facts should be admitted into so important a discussion. REV.)

Hemianopsia. HENRY D. NOYES. N. Y. Medical Record. April 4, 1891.

In considering hemianopsia as "a visual manifestation of intra-cranial disorder" a number of interesting points are clearly developed. The very large number of instances in which the dividing line in hemianopsia spares the fixation point is important. This occurs in most cases not only of the homonymous form, but also in those of double hemianopsia, as illustrated by some three cases. This immunity of central vision in

these cases cannot at present be adequately explained. Forster's suggestion of better blood supply to the cortical region corresponding to the fovea, is at present an hypothesis. In discussing the relation between the cortex and the retina Hun's case is quoted as significant. It must be remembered, however, that according to the experiments on animals the (ventral) lower portion of the cuneus is associated with the lower portion of the retina, while in Hun's case the lower portion of the cuneus is associated with the upper portion of the retina—an important difference. Sector defects in the field are more usually associated with disease of the cortex, while irregular defects are more likely to be subcortical.

As regards the perceptions of light, color and form it occurs, of course, that the loss of light perceptions necessarily involves the other two—but either of these alone—form or color may be lost independently. The two theories advanced to explain these are (1) separate areas for the two functions, lying beside one another, and (2) separate strata in the cortex lying above one another. It would be rash to say that either view was satisfactorily supported, but the latter seems to have rather the better support from the cases cited.

History of a case of sarcoma of genu of the corpus callosum, presenting symptoms of profound hysteria: With autopsy. CHARLES A. OLIVER, M. D. University Medical Magazine. Philadelphia, April, 1891.

The patient was a woman 43 years of age, who had suffered from severe mental strain associated with retroversion of the uterus. She exhibited symptoms shortly before her death which led to the diagnosis of profound hysteria, possibly combined with a gross intracranial lesion situated anteriorly and at the base of the brain.

The basis of this was the mutability of the ocular symptoms; the characteristic fields; the absence of any expressive motor changes; the condition of the fundus oculi, in association with the mental derangements; the loss of the senses of smell and taste; ovarian tenderness; abundant limpid urine without abnormal excreta; the absence of cephalgia, vomiting, vertigo, or any gross general symptoms of cerebral growth and a constant highly emotional condition.

In the left eye, vision was lost save in a small region to the nasal side of the visual field. Central vision for form for the right eye was but $\frac{1}{60}$th and could not be optically improved. The left pupil reacted only to the stimulation of the region mentioned. In the right eye a sluggish reaction of the pupil followed stimulation of either half of the retina. The field for color vision was very variable owing to the rapid fatigue due to the tests, the color first tested giving the largest field. The disturbance of vision was first noted by the patient, next smell and taste were lost by degrees and in the order named. Disturbance in hearing was not recognized, but upon testing, hearing was found deficient. Extreme lassitude was followed by her remaining continuously in bed. Visual illusion and hallucintions then appeared. The latter were of a very persistent sort, the former took the form of indefinite multiplication of special objects—all clearly projected. Tactile illusions followed and combined themselves with the visual ones. The muscle sense and that of pain and temperature appeared normal. There was no indications of any form of aphasia.

At the autopsy, the brain alone was examined. The tumor above mentioned was found attached to the genu. Its shape was hemispherical and its two greatest diameters six and five and one-half centimeters respectively. Its greatest bulk lay to the left of the median line. The uncinate gyri, the olfactory tubercles, the cephalic portion of the gyrus fornicatus and both optic nerves, but especially the left one, were the parts most affected.

The disturbances of vision are associated with the pressure on the optic nerves; those of taste and smell with that on the uncinate gyrus

and the neighboring olfactory pathways; that of hearing—which was specially deficient on the left side—with the greater bulk of the tumor on that side; and those of touch were not specially referred, but would most naturally fall in with the pressure on the anterior portion of the gyrus fornicatus. A histological examination of the compressed structures gave negative results.

Contributions to the Pathology of infantile cerebral palsies. B. SACHS, M. D. N. Y. Medical Journal. May 2, 1891.

One purpose of this article is to point out, by careful comparison of the clinical symtoms with the pathological findings, those cases in which the surgeon may properly interfere. Another purpose is to emphasize the view that a much larger number of these palsies than has been hitherto admitted, are of cerebral origin. In the pursuit of this latter end the author is but insisting upon views which he has previously advanced.

A brief table gives the conclusions which he has reached in the cases, the morbid lesion, form of palsy, distinguishing symptoms and conditions being brought together in three groups, arranged according to time of onset as "prenatal," "birth" and "acquired palsies." Further, an account of two cases is given in detail and illustrated by three plates.

The first case is that of a boy of eight years who was well uutil six years and a half of age, when he was seized with convulsions and developed right hemiplegia—the face included. He was hydrocephlic and and the head was found to be still enlarging. He had had repeated epileptic seizures involving the right hand only. His disposition was happy and his mental development good, though somewhat retarded. Later, he suddenly fell, without loss of consciousness. The hemiplegia was then found complete, the sphincters not being involved. Fever developed. Vision was disturbed, the disturbance ending in blindness. Speech became difficult and stupor was followed by coma. The motor nerves of both eyes became involved later. Death at end of eight weeks. The autopsy showed the brain much enlarged and quite smooth caudad. A cyst was found in the left ventricle and in this a large tumor (gliosarcoma), filling a large portion of the distended ventricle. Another large tumor was found near the top of the right temporo-sphenoidal lobe. Both tumors pressed on the brain axis and the eye symptoms are thus explained. The motor tracts in the cord were degenerated. The cyst, occupying a large portion of the motor area and due probably to a subpial hemorrhage, is offered as the explanation of the initial hemiplegia and the tumors, as that of the subsequent and fatal attack. The hydrocephalus is not considered as important in determining the course of events.

The second case was that of a chronic meningo-encephalitis in a boy of one year, due probably to a wide spread effusion of blood between the pia and the cortex at the time of birth.

Vergleichend-anatomische Untersuchungen über den Fornix und die zu ihm in Beziehung gebrachten Gebilde im Gehirn des Menschen und der Säugethiere. Von JACOB HONEGGER. Mit 10 Lichtdruk-Tafeln. Inaug. Diss. Zürich. Genf, 1890.

This pamphlet, which to say the least is a remarkable production, appears to have been printed at the same time in the Recueil Zoölogique Susse t. V, and thus the author was assisted in publishing his 234 pages of text and ten plates, on some of the more neglected parts of the brain. He opens with 76 pages of historical introduction, which is intended to fill the gap existing between the account of Burdach and the present day. This account is very full. His material for study comprised a long series of sections from man, calf, sheep, dog, pig, cat, rabbit, mouse, and from several birds, reptiles, amphibia and bony and cartilaginous fishes, many of these animals being represented by several series in different planes aud stained with gold, carmine, or Weigert's

haematoxylin. So much for his base of supplies. By comparison of this rich material the author proceeds to examine critically the structure of the cornu ammonis and the fascia dentata, striae Lancisii, psalterium fornix longus and fimbria, septum pellucidum and pedunculus septi pellucidi, columnae fornicis, tuber cinereum and corpus mamillare, decussatio subthalamica posterior and pedunculus corporis mamillaris, the bundle of Vicq d'Azyr and of v. Gudden, the fasciculus longitudinalis posterior, taenia thalami optici, ganglion habenulae, pedunculi conarii, Meynert's bundle (fasiculus retroflexus), taenia semicircularis and nucleus amygdalae.

The structures are treated from the purely anatomical side so that, even if we felt capable of reviewing the results, which we confess we do not, it would hardly be possible to do so in this place.

It is a valuable paper from the detail with which many of these neglected structures are discussed and the broad comparative basis which the author has for his conclusions. It is hard reading, and to this the subject matter and the style are both contributors. The phototype plates are artificially admirable, but would be aided by outline diagrams in each case, and as it is a paper for reference rather than continuous reading, an index would be a great assistance.

The epithelium of the brain cavities. By P. A. FISH. Proc. Am. Soc. of Microscopists. 1890. 1 plate.

The author studied the living epithelium or endyma in the brain cavities of the cat, using animals that were adults, six weeks old or newborn, and found ciliated cells in all cases. At the points of intrusion of the plexuses into the cavities, as in the paracœle (lateral ventricle), the covering cells were of the pavement form and without cilia. The discrepant statements concerning the existence of cilia of the brain cavities of adult man probably depend, as suggested, on the difficulty of obtaining really fresh material. The paper is accompanied by a useful bibliography.

Ueber Störungen der kompensatorischen und spontanen Bewegungen nach Verletzung des Grosshirns. A. V. KORÁNYI and J. LOEB. Archiv f. d. ges. Phys. Bd. XLVIII. 1891.

The research in question forms a further contribution to the analysis of the motor disturbances following lesion of the cerebral hemispheres in rabbits and dogs.

The first question taken up relates to the nystagmatic movements of the eyes in a rabbit fixed in the primary position upon a holder which can be revolved about a vertical axis. The direction of the nystagmus is referred to the animal, and the slower part of the oscillation is the one always designated. Upon rotating a normal rabbit, under the conditions just indicated, the nystagmus during rotation is in the opposite sense to the rotation, but when the rotation is stopped, it occurs for a short period in the same sense. In normal rabbits the direction of rotation, whether to the left or right, has no influence on the number of oscillations which are approximately the same in both cases, both during and after rotation. The authors rotated their animals ten times, then stopped the rotation and counted the number of subsequent oscillations. These were approximately the same for rotation to right or to the left in normal rabbits. When, however, the experiment was tried with rabbits from which the occipital portion of one cerebral hemisphere (always the left hemisphere in their experiments), had been removed, it was found that the direction of the rotation made a marked difference in the number of subsequent oscillations. A rabbit from which the occipital portion of the left hemisphere had been removed gave, after rotation to the right, a much larger number of subsequent oscillations than it did after rotation to the left. So too, these rabbits compensated by move-

ments of the body for rotation to the right better than for rotation to the left. During rotation to the left the rabbit must make nystagmatic movements to the right, and these were found to be more numerous when the rotation was to the left. In these cases then oscillations to right were the most readily obtained whether the animal was observed during or after rotation. It should be mentioned that when the frontal portion of the hemisphere was removed these differences in reaction were not observed.

When the lesion was made in the frontal portion of the brain, then compensatory movements were not affected. On the different effects of the lesion, according to its location, the authors lay no stress, but pass on to more general considerations. If after the injury to the brain there is a disturbance in compensatory movements—those of the eye being only one example—it must be due to a change in the irritability of the nervous mechanism involved in the reaction. This they think tends to favor the view of Goltz that "injury to the brain causes a decrease in the irritability of the lower centres in the spinal cord." In general they determined a greater tension in the trunk muscles on the side opposite to the lesion, but the explanation of this observation is not given.

The ear of man: its past, present and future—Lecture IX. in the Biological lectures delivered at the Marine Biological Laboratory of Wood's Holl in the summer session of 1890. Boston, Ginn & Co., 1891.

This lecture contains a general presentation of some observations on the morphology of the vertebrate ear coupled with some remarks on its physiology. The morphological portion is to appear more in detail in an early number of the Journal of Morphology. The author argues that the internal ear is derived by modification from the organs of the lateral line, and that it is to be regarded as representing two sense organs, one indicated by the utriculus and the other by the sacculus, each with a system of semicircular canals. Taking his departure from Allis' paper on the development of the lateral line organs in the fish, he shows how from the first sinking in of the auditory pit to the full development of mammalian ear, the process is parallel to that which takes place in the organs of the lateral line. When thus regarded, the Cyclostome ear—which has been a stumbling block to the comparative anatomists—appears as a simpler and less developed ear rather than an aberrant or degenerate one. The double nature of the organ is suggested by the double nerve supply—by what in the higher forms are considered the two branches of the auditory nerve—and by the fact that, considered schematically, the organ may be divided into equivalent portions, using the prolongation of the ductus endolymphaticus as an axis. If we accredit the anterior and horizontal canals to the utriculus we have the same number of groups of sensory cells as in the sacculus and its appendages. To be sure the latter has but one canal—the posterior, with its proper crista—but it also contains the *macula acustica neglecta* of Retzius, which, if the canal belonging to it had developed, would have established the numerical symmetry that the scheme demands. In speaking of the physiology the author lays much stress on the contradictions among the older authors who have investigated the semicircular canals and does not utilize the recent results like those of Delarge and Breuer, which are, if anything, more important.

Die Kopfnerven von Salamandra maculata im vorgerückten embryonalstadium untersucht. Von Baron Jos. von Plessen und Dr. Med. John Rabinovicz. Mit 2 lithographischen doppeltafeln und 4 Zinkographien im Text. München, J. F. Lehmann, 1891.

The plates in this paper are from the sections reconstructed after the method of His and are very instructive. In this salamander the troch-

learis nerve is wanting; the ganglion of the fifth nerve is double; the glossopharyngeus appears to have no ganglion, but simply to pass thro' the vagus ganglion; and the hypoglossus in accordance with the observations of others has but one root, the ventral. This, however, divides into a dorsal and ventral ramus, and in the dorsal ramus a distinct ganglion is to be seen, thus restoring the hypoglossus in these forms to the type of the spinal nerves—an important observation.

On out-lying nerve cells in the mammalian spinal-cord. By CH S. SHERRINGTON. Phil. Trans. Roy. Soc., 1890. 2 plates.

The author has examined the cord in man, the monkey (Bonnet, Jew and Rhesus), and dog, using sections from the cords of the cat, lion, calf, rat, mouse, rabbit and guinea-pig for comparison. The cells in question are those which lie outside of the gray matter among the white fibres, and they are conveniently subdivided for description into ventral, lateral and dorsal groups. The cells in these several localities are described, and they appear in each case similar to the cells of that portion of the gray matter near which they lie. By far the most interesting is the dorsal cells, which in a given section are scattered from the point of entrance of the dorsal roots to the column of Clarke. There is some evidence that these cells are bipolar—as is also the case for the cells in the column of Clarke—and the suggestion is made that we may have here homologues of the spinal ganglion cells still included in the substance of the cord, a suggestion which has much in its favor. From the descriptive nature of the paper the evidence for this view cannot be abstracted with advantage.

Die Ringbänder der Nervenfaser. Mitgetheilt nach Untersuchungen von DR. JOHANSON durch JUSTUS GAULE. Centralbl. f. Physiologie, Aug., 1891. Heft 11.

The communication is preliminary to the fuller paper now in press. Its bearing may be briefly indicated as follows: If the nerve of a frog, or rabbit be hardened in Erlyk's fluid for 14 days, teased in water and stained for an hour with haematoxylin (alum .5%, Häm 20%), the axis cylinder is slightly tinged and at irregular intervals bands are darkly colored and are to be seen in the medullary sheath. This appearance it is argued is due to the presence here of some substance taking the haematoxylin stain and not to an insignificant deposit of the dye. These bands occupy the position of the well known clefts of Schmidt and Lantermann. They have a suggestion of fibres in them. Such is the appearance in May frogs. In June frogs the picture changes, and there is a clearly marked spiral fibre surrounding the nerve at these points. At this time, June, the axis cylinder of the nerves is small and shrunken. Later it assumes the full appearance found in the spring (May), frogs. This condition of the axis cylinders the authors associate with the proverbial misbehaviour of the June frogs when used for nerve-muscle work. It is also plain that this condition of the nerves occurs at the breeding season, and the influence of the reproductive process on these bands and the possibility of their being related to nuclear substances, are the aspects of the case which most interest Gaule.

The Journal of Comparative Neurology—a quarterly periodical devoted to the comparative study of the nervous system. Edited by C. L. HERRICK, Professor of Biology, etc., in the University of Cincinnati. Robert Clark & Co., Cincinnati, Ohio. Vol. I, No. 1, March; No. 2 June, 1891.

It is certainly desirable that the papers on comparative neurology should be grouped in some one publication, and the opportunity for this is offered by the new Journal. Original papers, reviews, notes on technique, bibliography and an editorial have formed the contents of the

numbers thus far issued. In the first number the editor comments on some of the open questions, and in the second, as bearing on the relations of neurology to psychology, gives an historical account of the ideas on localization of function in the brain.

Running through both numbers is a laborious study of the avian brain by C. H. Turner, in which, for one thing, he tests the taxonomic value of the brain of birds, with suggestive results. In the first number the editor writes on "Illustrations of the Architecture of the Cerebellum." Under this head he presents the view that the superficial layer of the cerebellar cortex—the molecular layer—is, in part at least, derived from cells forming the walls of the recessus lateralis—a view which certainly requires more evidence to support it than is here given.

The remaining papers, three in number, are studies in comparative anatomy.

A LABORATORY COURSE IN PHYSIOLOGICAL PSYCHOLOGY.

By Edmund C. Sanford, Ph. D.

(*Second Paper.*)

III.—TASTE AND SMELL.

Sensations of Taste.

Apparatus. A potato and an apple; standard solutions of sweet, bitter, sour and salt; camel's-hair brushes; battery and zinc electrodes. The standard solutions should be made of two strengths, the stronger for testing the individual papillæ and the weaker for finding the least proportion tastable. The following proportions of tastable substances and water are convenient. Stronger solutions: Sugar, 40:100; Quinine, 2:100; Tartaric Acid, 5:100; Salt, saturated solution. Weaker solutions, (for which the water itself should be without taste): Sugar, 5:100; Quinine, 2:100 000; Tartaric Acid, 5:1000; Salt, 2:100. Special solutions of Sugar for Ex. 52: 20:100, 18:100, 16:100, 14:100, 12:100, 10:100.

49. Much of what is commonly called taste is really taste plus smell or touch or both. With the eyes shut and the nostrils held try to distinguish, by taste alone, between small quantities of scraped apple and potato, placed upon the tongue.

50. Distribution of the Organs of Taste. *a.* Using the weaker solutions and operating with a mirror or on another person, find out as nearly as you can in what part of the tongue the strongest sensations are produced by each. Test the tip, the sides, the back and the middle, putting on the solutions with a camel's-hair brush and rinsing the mouth as often as necessary. Try also the hard and soft palates. *b.* Dry the tongue with a handkerchief and test the individual fungiform papillæ with the stronger solutions, applying them with fine camel's-hair pencils. It will be found possible to get taste sensations from the single papillæ, though perhaps not all four from each. Rinse the mouth as needed. *c.* Test the surface of the tongue between the papillæ and observe that no taste sensations follow.

On *a* cf. Kittmeyer: Geschmacksprüfungen, Göttingen Diss. 1885. On *b* and *c* cf. Oehrwall, Untersuchungen über den Geschmackssinn, Scandinav. Archiv f. Physiol. Bd. II, 1890, pp. 1-69; see also abstract by the author in the Zeitschrift f. Psych., Bd. I. 1890, p. 141.

51. Minimal tastes. *a.* Find what is the greatest dilution of the weaker solutions in which the characteristic tastes can still be recognized. The same quantity, *e. g.*, half a teaspoonful, should be taken into the mouth at each trial and may be swallowed with advantage. Rinse

the mouth thoroughly as required. The following are the proportions given by Bailey and Nichols for male observers: Quinine, 1:390 000; Sugar, 1:199; Salt, 1:2240; for Sulphuric Acid, which they used instead of Tartaric, the proportion was 1:2080. *b*. The intensity of the sensation and the greatest dilution still tastable depend on the number of taste organs stimulated. Take a portion of one of the solutions of just tastable strength found in *a*, add an equal quantity of water and take a large mouthful of the mixture. The characteristic taste will still be perceived, perhaps more strongly than before.

On *a* cf. Bailey and Nichols, The Delicacy of the Sense of Taste, Nature, XXXVII, 1887-88, 557; and Lombroso und Ottolenghi, Die Sinne der Verbrecher, Zeitschrift für Psychologie Bd. II, 1891, pp. 346-48. Camerer, Die Grenzen der Schmeckbarkeit von Chlornatrium in wässriger Lösung, Pflüger's Archiv, II, 1869, 322. On *b* cf. Camerer, Die Methode der richtigen und falschen Fälle angewendet auf den Geschmackssinn. Zeitschrift für Biologie, XXI, 570.

52. Discriminative sensibility for taste. For a rough determination test with the solutions of sugar indicated above, taking first a small quantity of the standard 20% solution, then an equal quantity (the equality is important) of one of the weaker solutions, or first one of the weaker and then the standard, until a solution is found that is just recognizably different from the standard. Make this determination several times. The excess of sugar in the standard solution over the amount in the solution just observably weaker set in a ratio to the total percentage of sugar in the standard measures the sensibility. Some experimenters may be able to distinguish the 18% from the 20% solution; their sensibility would then be expressed by the ratio 2:20.

On such experiments as this cf. Keppler, Das Unterscheidungsvermögen des Geschmacksinnes für Concentrationsdifferenzen der schmeckbaren Körper. Pflüger's Archiv, II, 1869, 449.

53. Electrical Stimulation. *a*. Using a constant current and two zinc electrodes one above, the other under the tongue notice the sour taste at the positive pole and the alkaline at the negative.

On the sensations of taste in general cf. von Vintschgau, Physiologie des Geschmackssinne, Hermann's Handbuch der Physiologie, III, (pt. 2) pp. 145-224; Oehrwall, *op. cit.* On acid tastes and chemical composition cf. Corin, Action des acides sur le goût, Archives de Biologie, VIII, fasc. 1.

SENSATIONS OF SMELL.

Apparatus. Essence of cloves; olfactometer of Zwaardemaker; camphor gum; yellow wax; a dozen small wide mouthed bottles. The essence of cloves is made by adding one part of oil of cloves to fifteen parts of alcohol[1] and may be diluted with water, itself odorless, to make the solutions required in Ex. 54. For that experiment dilutions of the essence that will give the following proportions of oil of cloves will be found convenient: 1:50 000; 1:100 000; 1:200 000; 1:300 000; 1:400 000; 1:500 000. The olfactometer of Zwaardemaker in simple clinical form may be bought of Mechaniker Harting Bank, Utrecht, at 1.50 mk.; but

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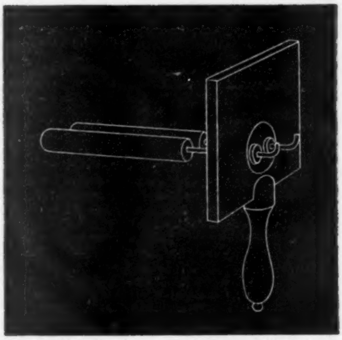
[1] Whether this essence is of the same strength as that used by Lombroso and Ottolenghi in their experiments to which reference is made below, the writer does not know.

its construction is so simple that it may easily be made in the laboratory. It will be most convenient if made double as shown in the accompanying cut. The instrument consists of a light wooden screen, say six inches square, provided with a handle below for easier holding. Through this screen, a little below the middle, a hole an inch and a half in diameter is bored, and fitted with a large cork. The cork in turn is pierced with two holes side by side an inch apart and of such size as to fit tightly upon the glass tubes next to be mentioned i. e. about 7 mm. The glass tubes should be long enough to leave 10 cm. free behind the screen and about 3 cm. free in front. The front ends are bent upward at right angles for insertion in the nostrils.



The odorous substances used in this instrument are applied in the form of tubes that slide over the glass tubes behind the screen. The simplest and best for persons of normal keenness of smell are pieces of red rubber tubing 10 cm. long and of such bore as just to slide freely over the glass tubes (8 mm.). These pieces of rubber tubing should themselves be slipped into pieces of tight fitting glass tubing so as to prevent the spread of the odor from their outer surface. For Ex. 57 another odor tube, this time of yellow wax will be needed. This can easily be made by placing a glass tube (of the size of the air tubes used in the olfactometer) inside a tube such as is used to cover the rubber odor-tubes and filling the space between them with melted wax. The inner tube may then be warmed by running hot water through it till it can be withdrawn. The principle upon which the instrument works is this, namely, that the intensity of the odor varies directly as the surface of odorous substance exposed. When the odor-tubes are slipped onto the glass tubes of the olfactometer and pushed back until their ends are flush with those of the glass tubes, the air inhaled through the latter contains few or no odorous particles because no odorous surface is exposed. When, however, the odor-tubes are pulled a little away from the screen so that they extend over the ends of the glass tubes, they expose the odorous surface inside them to the current of air inhaled. The strength of the odor is proportional to the area exposed, or since the bore does not change, to the length of odor tube that extends beyond the glass tube. This last can be conveniently measured by a scale (*e. g.* centimeters and half centimeters) scratched on the inner glass tubes. The length of odor tube corresponding to a just observable odor will, of course, differ with different tubes, from person to person, and with the temperature, but tubes of red rubber are reported to give satisfactory results both as to original intensity and the constancy with which they keep their odor through considerable periods of time. The length of red rubber odor tube required by Zwaardemaker himself for a just observable odor at 18° C. is 7 mm. In use the upward turned end of one of the glass tubes is inserted in the forward part of the nostril and the subject draws his breath in the way most natural to him in smelling—the proportion of odorous particles is greater, however, when the current of air is slow than when it is rapid. The inside of the glass air tubes will need to be cleaned of adhering odorous particles from time to time.

On the olfactometer and its method of use see the following papers of Zwaardemaker: Die Bestimmung der Geruchschärfe, Berliner Klin. Wochenschrift, XXV, 1888, No. 47, p. 950 (abstract of the same, British Med. Journal, 1888, ii, 1295); also Lancet, London, 1889, i. 1300. On an improved form adapted to liquid substances (and thus to substances of known and relatively simple chemical composition) see, Compensation von Gerüchen mitteist des Doppelreichmessers, Fortschritte der Medicin, VII, 1889, 725 ff.

54. Minimal odors. The keenness of smell may be tested with dilute solutions of odorous substances or with the olfactometer; it will be instructive to test by both methods. *a.* Tests with solutions. Pour small quantities of the solutions of oil of cloves described above into little wide-mouthed bottles, filling each to about the same height. Mark all in an inconspicuous manner. Set the bottles on a table a foot apart in a place where there is moderate circulation of air, in the order of the strength of their solutions, beginning with the water and following with the weakest solution and so on. Require the subject to smell of the bottles in succession without lifting them from the table, beginning with the water, and to indicate that in which he first recognizes a characteristic odor. If the solutions stand for any length of time where they are subject to evaporation it will be safer to prepare fresh ones before undertaking a new test. Other precautions will suggest themselves, as for example, the use of bottles of the same size and shape, and care in filling them that some of the solution is not left clinging near the mouth. The just observable solution will probably be found to lie between the 1:100 000 and 1:400 000. *b.* Tests with the olfactometer. Test the sides of the nose separately. Push the odor-tube on till its end is flush with that of the glass tube, insert the bent end of the latter into the nostril as described above, and gradually lengthen the exposed surface of the odor-tube till its odor is just discernable. Note in millimeters the length exposed.

On *a* cf. Bailey and Nichols, The Sense of Smell, Nature, XXXV, 1886-87, 74; Lombroso and Ottolenghi, *op. cit.* under Ex. 51. On *b* cf. Zwaardemaker, Sur la norme de l'acuité olfactive (olfactie), Archives Néerlandaises, T. XXV, pp. 131-148.

55. Discriminative sensibility for odors. Using the double olfactometer with both odor-tubes drawn out far enough to give an unmistakable odor, but not too strong a one, say both drawn out 5 cm., find how far one or the other must be drawn out (or pushed back) to make the odor which it gives just observably stronger (or weaker) than that of the other. The test should be made with one side of the nose only, (there is frequently a difference in sensitiveness between the two sides, due to mechanical obstruction or other cause) unless for some reason a bilateral form of experiment is desirable. Try a number of times, but be careful to avoid fatigue.

56. Fatigue of smell. *a.* Hold a piece of camphor gum to the nose, and smell of it continuously, breathing in through the nose and out through the mouth, for five or ten minutes. A very marked decrease in the intensity of the sensation will be observed, reaching perhaps even to complete loss of the odor. *b.* It is important, however, to observe that fatigue for one substance does not cause obtuseness for all other substances, though it does for some. Smell of some essence of cloves and of some yellow wax, then fatigue for camphor as in *a* and smell of the essence of cloves and of the wax again. The odor of the wax will probably be fainter, that of the essence of cloves unaffected.

Cf. Aronsohn, Experimentelle Untersuchungen zur Physiologie des Geruchs, DuBois-Reymond's Archiv, 1886, pp. 321-57.

57. Compensation of odors. *a.* Experiment with the olfactometer on one side of the nose as follows. Hold against the end of the rubber odor-tube another odor-tube of wax, partly covered on the inside by a glass tube of the same size as that used in the olfactometer, in such a way that the air must pass through both to reach the nose. Then gradually increase the length of the rubber tube exposed till the odor of the

wax is no longer perceived. If the experiment is carefully performed a point may be found where the two odors nearly compensate and the resulting sensation approaches zero. If the rubber is lengthened beyond this point its odor overpowers that of the wax; if it is shortened it is overpowered by that of the wax. A *mixture* of the odors is hardly to be found. *b.* Repeat the experiment, using the double olfactometer with rubber on one tube and wax on the other. The compensation will be observed as before though each side of the nose receives a separate stimulus. If the two sides of the nose are not equally keen scented the proportions of the tubes that give compensating odors will not be the same as before. Care should of course be taken to avoid fatigue.

Cf. Zwaardemaker, Compensation von Gerüchen mittelst des Doppelreichmessers. Fortschritte der Medicin, VII, 1889, No. 19. pp. 721-731.

On smell in general, beside the literature already cited cf. von Vintschgau, Physiologie des Geruchssinnes, Hermann's Handbuch der Physiologie, III, (pt. 2) pp. 225-286, and the literature there cited.

IV.—HEARING.

Sounds in General.

Apparatus. A watch, 2 yards of three-eights inch rubber tubing, 2 tuning-forks (the ordinary A forks sold at music stores at 25 cents each will answer if a couple are chosen that prolong their sound well), and a hammer. A watch is not an ideal instrument for testing acuteness of hearing, but has the advantage of ready accessibility and simplicity in use.

For other special instruments for testing acuteness of hearing cf. Hensen, Physiologie des Gehörs, Hermann's Handbuch der Physiol. III, pt. 2, pp. 119-120 and the references there given; also Jacobson, Ueber Hörprüfung und über ein neues Verfahren zur exacten Bestimmung der Hörschwelle mit Hülfe elektrischer Ströme, Du Bois-Reymond's Archiv, 1888, 189. For apparatus for testing the discriminative sensibility for sounds cf. (for noise) Starke, Die Messung von Schallstärken Wundt's Philos. Studien, III, 1886, 266, and Zum Mass der Schallstärke *Ibid*, V, 1889, 157; (for tone) Wien, Ueber die Messung der Tonstärke, Inaug. Diss. Berlin, 1888, also in Wiedemann's Annalen, XXXVI, 1889, 834—857.

On hearing in general cf, Helmholtz, Sensations of Tone, Eng. tr. by Ellis, Hensen, *op. cit.;* Stumpf, Tonpsychologie; Wundt, Physiologische Psychologie.

58. Minimal sounds. *a.* Experiment in a large room, furnished (to lessen the echoes) and as free as possible from noise. Let the subject be seated with his side toward the experimenter, his eyes closed and his ear upon the other side plugged with cotton. Let the experimenter then find what is the greatest distance at which the subject can still hear the tick of a watch held at the level of his ear and on the prolongation of the line joining the two. This is easily done with sufficient accuracy by drawing a chalk line on the floor, marking off feet or meters and fractions upon it and estimating by eye the point of the line directly under the watch. Try several times for each ear both when the watch is being brought toward the ear and when it is being carried away. The experimenter should from time to time cover the watch with his hand to discover whether or not the subject really hears or is under illusion. For normal ears the distance found may vary from 2.5 m. to 4.5 m. and may even rise to as much as 9 m. *b.* The subject should notice in this experiment the very marked intermittences of the sound when just upon the limit of audibility. It will for a few seconds be heard above doubt and a few seconds later will as certainly not be heard.

On *a* cf. von Bezold, Schuluntersuchungen über das kindliche Gehörorgan, Zeitsch. f. Ohrenheilkunde, XIV, 1884-85, and XV. 1885-86. This paper gives the results of numerous tests on Munich school children, not only with the watch but also with the acoumeter of Politzer and with whispered speech. On *b* cf. Urbantschitsch, Ueber eine Eigentümlichkeit der Schallempfindungen geringster Intensität, Centralblatt f. d. medic. Wissensch., 1875, 625; N. Lange, Beiträge zur Theorie der sinnlichen Aufmerksamkeit und der activen Apperception, Wundt's Philos. Studien, IV, 1888, 390; Münsterberg, Schwankungen der Aufmerksamkeit, Beiträge zur experimentellen Psychologie, Heft 2, 1889, 69.

59. Auditory fatigue. Cause an assistant to strike once with a hammer on the floor, or to clap his hands. With the ears open a single

sound, or at most a single sound and transient echoes are heard. If, however, the ears are kept closed with the fingers till half a second or more after the stroke (the time may easily be fixed by rapid counting), the fainter echoes will be heard like a new stroke. In the first case, fatigue from the original sound deadens the ears to the fainter echoes, though they may still be heard by attentive listening; in the second case they are more strongly heard because the closed ears are unfatigued. The sound produced by the simple opening of the ears without any objective stroke will be less if the finger is not put into the ears, but presses the *tragus* back upon the opening. *b*. Insert in the openings of the ears the ends of a rubber tube. Strike a tuning-fork and set it upon the tube at such a point that it sounds equally intense to the two ears. (The sound will then probably appear to be located in the head midway between the ears—at least not nearer one than the other). After a few seconds strike the tuning-fork again, pinch the tube on one side, say the left, so as to shut off the sound from the ear on that side, set the tuning-fork on the tube and keep it there till the sound has become rather faint. Then allow the pinched tube to open and notice that the sound is now stronger on the left than the right and apparently located on the left. Cf. later experiments on the location of tones.

On *a* cf. Mach, *op. cit.* (under Ex. 39) p. 58. On *b* cf. Urbantschitsch, Zur Lehre von der Schallempfindung, Pflüger's Archiv, XXIV, 1881, 574-579 and references there given. See also Stumpf, Tonpsychologie, I, 360-363, where other instances of fatigue are cited.

60. Inertia of the auditory apparatus. *a*. Inertia tending to keep the auditory apparatus out of function can be demonstrated as follows. Place the ends of a rubber tube in the ears and set upon the middle of it a low tuning-fork sounding as faintly as possible. Notice that the sound does not reach its maximum intensity for an appreciable length of time; if the fork is barely audible this may be as much as a second or two. Be careful not to increase the pressure of the fork upon the tube after first setting it on; for that will produce an objective strengthening of the tone; and allow an interval of several seconds between the tests so that the auditory apparatus may again come completely to rest. A tuning-fork that will preserve these minimal vibrations for some seconds and complete freedom from distracting noises will be found necessary for success.

Cf. Urbantschitsch, Ueber das An- und Abklingen acustischer Empfindungen, Pflüger's Archiv, XXV, 1881, 323.

61. Noise. Whether or not there is a distinctive sensation of noise different from that of a mass of short, dissonant and irregularly changing tones is yet under debate, with something of the weight of authority in favor of such a sensation. A little attention to the noises constantly occurring, especially to their pitch, will easily convince the observer that a tonal element is present. This is striking when resonators (cf. notes on apparatus for simultaneous tones) are used, for they pick out and prolong somewhat the tones to which they correspond, but they are not indispensable. On the other hand, attention to musical tones will often discover the presence of accompanying noises.

Cf. Wundt, Physiologische Psychologie, I, 420; Stumpf, Tonpsychologie, II, 497-514; also Brücke *op. cit. sub* 69; Exner, Pflüger's Archiv XIII, 288 ff.; Mach, Analyse der Empfundungen, Jena, 1886, 117.

62. Silence. When circumstances promise absence of external sounds, notice that many are still present and distinct, though faintly heard. Notice also the pitch and changing character of the subjective sounds to be heard. Our nearest approach to the sensation of absolute stillness is this mass of faint inner and outer sensations.

Cf. Preyer, Ueber die Empfindung der Stille, Sammlung physiologischer Abhandlungen, Jena, 1877, pp. 67-72. This section on Silence is a portion of Preyer's study, Ueber die Grenzen der Tonwahrnehmung.

SINGLE AND SUCCESSIVE TONES.

Though musical terms are occasionally used in these experiments and some discrimination of tones is necessary, it is believed that nothing is required beyond the average ability of the unmusical.

Apparatus. The upper limit of pitch may be tested with the disk siren, with tuning-forks, with steel cylinders and with little whistles of adjustable length. The last two instruments are most commonly used and may be had from almost any dealer in physical apparatus, the cylinders from $10 upward, the whistle (designed by Galton), at about $5.00. The Cambridge Scientific Instrument Co., St. Tibb's Row, Cambridge, Eng., makes the whistle in two patterns, a simple one at £1. 5s and a more elaborate one at £6. R. König, 27 Quai d'Anjou, Paris, also makes two kinds, one at 12 the other at 20 fr., the latter probably a better instrument than that of the Cambridge Scientific Instrument Co. at £1. 5s. For description and prices of the more expensive kinds of apparatus consult König's catalogue.

For testing the lower limit of pitch large tuning-forks may be used or the difference tones of small tuning-forks or of stopped organ pipes. Large tuning-forks could probably be made well enough for demonstrative purposes by almost any blacksmith and their pitch determined approximately by making them record their vibrations graphically upon a piece of smoked glass for ten seconds. The large fork with sliding weights (24-16 double vibrations per sec.) manufactured for this purpose by König costs 300 fr. and his set of high pitched forks for the difference tone method costs 340 fr.

For Ex. 65 and others that follow, almost any musical instrument of a considerable range of pitch will answer.

For Ex. 65*c*. use a piston whistle such as is sold in toy stores at five cents. Two that are in the laboratory here reach the proper pitch when their pistons are pushed in as far as possible. It would be easy, if still higher tones were needed, to so alter the whistles as to make these possible.

For Ex. 67 prepare a series of forks each differing from the next by about three vibrations a second. Half a dozen C forks such as are sold at the music stores will answer, if those are chosen that prolong their sound well. Take one of them as a standard and make the next sharper by filing a little at the free end of the prongs till it beats (cf. Ex. 75) with the standard three times in a second. Count for 10 seconds, if possible, and divide the total count by 10 to find the rate per sec., counting the first beat nought. (For precautions to be used in attempting an accurate count cf. Helmholtz, *op. cit.* 443 where Ellis gives all necessary particulars.) Having brought this fork approximately to three beats per sec. take it as a standard and make the next fork three beats sharper than it in the same way and so on. Make also a series o forks differing by three vibrations each, which shall be flatter than the normal C. It will be well to make a recount for greater accuracy after the forks have had a chance to cool. In order to flatten the forks a little as mentioned in Ex. 67 little riders of rubber tubing may be placed upon the prongs. Make these riders by cutting off quarter inch bits from tubing that will fit tightly upon the prongs of the forks. For the resonance bottles mentioned in the same experiment take a four ounce wide mouthed bottle and tune it to the forks by gradually closing its mouth with a bit of glass (*e. g.* a microscope slide). When the amount of closure is found which gives the greatest intensity of sound, fix the glass in position with wax. (For picture and description of such bottles see Meyer, *Sound*, pp.102-103). A standard instrument for giving such small differences of pitch as are represented above by the sharpened forks is made by Anton Appunn of Hanau a. M. under the name of a *Tonmesser*. (See picture and description in Wundt's Physiologische Psychologie, I,

431 f.) and costs for the complete instrument, with pitches ranging from 32 to 1024 vibrations per sec. and a blowing table, 1060 marks. Single octaves without the blowing apparatus range in price from 150 to 320 marks. The same maker also offers a set of forks giving a series of tones differing each from the next by a small fraction of a vibration (*Tondifferenz-apparat*) at 96 marks. See his price list also for other apparatus useful in the experiments of this section.

For Ex. 69 a hydrogen generator (cf. an elementary chemistry) will be necessary. In blowing the hydrogen and air bubbles it will be found convenient to have the mixed gases in one large bottle and to force them out by pouring in water.

For Ex. 70 a pint bottle.

Some of the apparatus suggested at the beginning of the next section will also be found useful in this.

63. Highest tones. With the apparatus at hand for the purpose, find what is the highest audible tone; i. e., if the cylinders are used, the shortest cylinder which still gives a ringing sound on the stroke of the hammer, or if the whistle is used, the closest position of the plunger at which a tone can still be heard beside the rush of air. If a number of persons are tested it is not improbable that some will yet hear the tone after it has become inaudible for the rest.

64. Lowest tones. *a.* If low pitched tuning-forks are at hand, find what is the slowest rate of vibration that can yet be perceived as a tone. In some physiological laboratories electric tuning-forks or interrupters are at hand which have vibration rates of 25 per second. Low tones can be heard from these, though they have many overtones. The latter can be partly damped by touching the tines mid-way of their length with the finger and partly avoided by bringing the ear not to the free end but to a point somewhat further toward the handle. The determination of the lower limit of audible pitch is difficult and uncertain because of the great difficulty which observers, even those of trained ear, find in distinguishing these lowest tones from their next higher octaves. *b.* The general character of these deep tones can be demonstrated with sufficient clearness upon the contra octave (C_1–C) of a church organ if one is accessible and tuning forks are lacking.

65. Some characteristics of high and low tones. *a.* High tones are smoother than low tones. This is clear with almost all tones used in music, and particularly so with those of reed instruments. It is largely due to the beating of the partial tones (see Exs. 82 ff. and 75 ff.) among themselves and even with the fundamental tones. Play the scale of the instrument at hand from the lowest to the highest, or sing the ascending scale. The difference of roughness is observable also with simple tones, but only at lower pitches and is even there less marked. *b.* High tones except the very high, produce a more intense sensation in proportion to their physical intensity than do low tones. Strike a low tuning-fork in which the over-tones are to be heard and notice that the over-tones can be heard at a greater distance than the proper tone of the fork. *c.* Some high tones are particularly strengthened by the resonance of the outer passage of the ear. These generally lie between c^4 and c^5 and give to the tones of this octave a superior strength, and ear-piercing quality. They may be demonstrated easily with a small piston whistle like that mentioned above. Find by adjustment of the piston the point at which the tone is most piercing. Insert in the outer ends of the ear passages bits of rubber tubing half an inch long (which will change the resonance of the passage, making them responsive to a lower tone) and sound the whistle again. The piercing quality will be gone and the tone appear decidedly weaker. Remove the bits of tubing and sound the whistle as before; the original quality and intensity reappear.

d. Very closely associated with the pure tonal sensations are certain of a spatial quality. Compare in this respect the sensations of the tones observed in Ex. *c* above, or better still those of Ex. 63, with those of Ex. 64 or any other deep tones. Play the scale through the complete compass of any instrument, keeping this quality in mind. *e.* The emotional shading of tones changes with their pitch. Recall the descriptive terms used: Deep, low, tuneful, sharp, acute. Play the scale and judge of the appropriateness of these terms to match the shades of feeling that mark the tones of low, middle and high pitch, distinguishing those that refer to pitch from those enumerated in Ex. 86 which refer to timbre.

Cf. Stumpf. Tonpsychologie, I, 202-218, II, 56-59, 514 ff.; also Mach, *op. cit.* under 61, p. 120 ff. On *c* and *e* cf. Helmholtz, Sensations of Tone (2nd Eng. ed.) p. 179 and p. 69. On *d* cf. James, Psychology, II, 134 ff.

66. Recognition of absolute pitch. This experiment can, of course, give accurate results only with those of very decided musical ear and skill, but it may be tried with any subject that knows the names of the notes. *a.* Strike various notes in different parts of the scale of the instrument and require the subject to name the note given. Record the note struck and the subject's answer. He should be seated with his back toward the experimenter or should keep his eyes closed.

Cf. Stumpf, *op. cit.* I, 305-313, also II, index, *Höhenurteile*, for experiments on trained musicians.

67. Just observable difference in pitch. *a.* Test as follows with the set of mistuned forks mentioned above. Let the subject pick out from the mistuned forks that which sounds to him most like the normal fork, striking and holding them successively (never simultaneously) over a resonance bottle. If all of them seem more than just observably different let him put the riders (described above) on the one that is next higher and gradually lower the pitch by sliding them toward the ends of the fork till the two, heard successively, are just different and no more. The experimenter may then determine the error of the subject in vibrations per second approximately by counting the number of beats produced by the forks when sounded together. If the number of beats per second is less than 2 or more than 6 it will be best to get the difference in pitch with some other of the forks first, so as to avoid too slow or too rapid counting, and from that to arrive at the difference from the standard fork. Repeat the test several times and average the result, but take care to avoid fatigue. This experiment will not be refined enough for testing those of keen musical ear.

Cf. Preyer, Grenzen der Tonwahrnehmung, Sammlung physiologischer Abhandlungen, I, (Jena, 1877) 26 ff.; Stumpf. *op. cit.* I, 296-305; Luft, Wundt's Philos. Studien, IV, 514.

68. Differences in pitch that are just recognizable as higher or lower. It is easier to recognize a difference than to tell its direction. *a.* Experiment as in 67*a*, but require the subject this time to pick out and adjust a fork that is just observably sharper or flatter than the standard.

On *a* cf. Preyer, *op. cit.* 28, 36. For experiments on extremely unmusical subjects cf. Stumpf, *op. cit.* I, 313-335.

69. Number of vibrations necessary to produce a sensation of pitch. Arrange an apparatus for blowing soap-bubbles with a mixture of hydrogen and air. Blow bubbles of different sizes and touch them off with a match, either in the air, or, if proper precaution is taken to prevent the ignition of the mixed gases in the vessel and any resonance in the pipe, while still hanging. The explosion of these bubbles is supposed to produce a single sound wave. The pitch of the sounds produced cannot be accurately given, but the report of the large bubbles is distinctly deeper than that of the small ones.

Cf. Brücke, Ueber die Wahrnehmung der Geräusche, Wien. Sitzb., 3te Abth., XC, 1884, 199-230.

70. The apparent pitch of tones is affected by their timbre, tones of dull and soft character regularly seeming lower in pitch than those that are brighter and more incisive. Require the subject to pick out on some stringed or reed instrument the tone corresponding to that produced by blowing across the mouth of a medium sized bottle. Too low a note will generally be chosen, at least by those without special musical training. The tones should be sounded successively, not at the same time, during the test. Afterward they may be sounded together and the pitch of the bottle determined approximately by finding with which tone of the instrument its tone makes the slowest beats (cf. Ex. 75). It should be remembered, however, that it will be possible to get beats also with tones an octave lower and an octave higher than that corresponding most nearly with the true pitch of the bottle tone. *b*. Repeat the experiment, taking the pitch of the bottle first with the voice and then finding the tone on the instrument corresponding to that sung. The illusion will probably disappear when the test is thus made.

Cf. Stumpf, *op. cit.* I, 176, 227-247, especially, 235-245.

71. Recognition of musical intervals. Cause a familiar air to be played, first in the octave of *c* and then in that of c'' in the same or another key. Even those of no musical training will easily recognize that the air (i. e. the succession of musical intervals in fixed rhythmical relations) is the same in both cases; and any mistake or variation will be noticed as easily as if the air had been repeated at the first pitch. The power of recognizing intervals is very much more highly developed in persons of musical training, but any one that can whistle a tune at one pitch and repeat it recognizably at another undoubtedly has the rudiments of it.

For exact methods of testing the accuracy of the power of recognizing intervals cf. Preyer, Ueber die Grenzen der Tonwahrnehmung, Jena, 1876, pp. 38-64; and Schischmánow, Untersuchungen über die Empfindlichkeit des Intervallsinnes, Wundt's Philos. Studien, V, 558-600 and the references there given.

72. Pitch distances. Beside the interval relations of tones, and overshadowed by them in musicians, are certain relations of separateness or distinctness or distance in pitch, which do not depend on the ratios of vibration rates. Equal musical intervals (i. e. intervals between tones that have vibration rates in a fixed ratio to each other, e. g. *C D* and c'' d'') do not correspond to equal pitch distances. Sound the half tone interval *cc*-sharp through the range of the instrument, beginning in the bass and ascending. Notice the increasing distinctness and separation of the tones as the interval is taken higher and higher. For the very highest tones there is probably a decrease of separateness again. The difference is most striking, however, with intervals smaller than those in common use, e. g. with quarter or eighth-tones. On the harmonical (cf. notes on apparatus at the beginning of the next section) strike in succession the *c-sharp* and *d* keys in the four lower octaves beginning with the lowest. In this instrument the *c-sharp* key is given to another *d*, a comma, or about one-ninth of a tone, flatter than the regular *d* of the scale.

Cf. Stumpf, *op. cit.* I, 249-253; Lorenz, Untersuchungen über die Auffassung von Tondistanzen, Wundt's Philos. Studien, VI, 1890, 26-108; also a prolonged discussion between Wundt and Stumpf (and Engel) in succeeding numbers of the Studien and in the Zeitschrift für Psychologie. Helmholtz, *op. cit.* pp. 264-65, 285, 287.

73. The effect of a given tone in a melody depends in part on the succession of tones in which it stands. Cause a simple air, in which the same tone recurs in different successions of tones, to be played and notice the difference in effect in the different circumstances.

Mach, *op. cit.* under 61, p. 130-131.

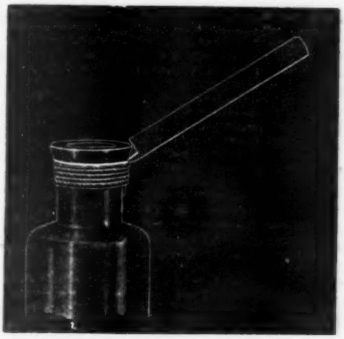
74. Tones that vary irregularly in time and in pitch are unpleasant. Test with a piston whistle.

Simultaneous Tones.

Apparatus. For the experiments of this section access to some large musical instrument is essential, and a reed instrument is to be preferred to a piano if only one is to be used. A parlor organ will answer in most cases, but sometimes the specially tuned Harmonical designed by Ellis to illustrate the theories of Helmholtz (see description of the instrument in his translation of Helmholtz's Sensations of Tone, pp. 466-469, also 17, 22 and 168), would be better. This instrument is made as an aid to science by Messrs. Moore and Moore, 104-105 Bishopsgate St., Within, London, E. C., at the very low price of from £8-5 to £10. For the proper tuning of the instrument, however, a set of 19 forks is necessary costing £3-10 extra. In many of the experiments a sonometer can take the place of a piano. A sonometer is simply a long flat box with a very thin top which serves as a sounding board for the strings that are stretched over it. One may be had from any physical instrument dealer at from $10.00 upward, or can be made by a carpenter. For directions for making and dimensions see Mayer, Sound, (Appleton & Co.) pp. 129-130.

For more perfect apparatus for the study of beats, difference tones, compound tones, timbre, etc., consult the catalogues of König, whose address has already been given, and of Anton Appunn, Nürnbergerstrasse 12, Hanau, a. M., Germany. Both make resonators, those in spherical form made by König are best and most expensive. A series of 10 corresponding to the first ten partial tones of *c* (128 vibrations) costs 110 fr.; a series of 19, 170 fr. Appunn's in conical form cost from 27 mk. for a set of 9 to 80 mk. for a set of 29.

The bottle whistles mentioned in Ex. 75 are easily made by fitting a piece of rubber tubing to the lip and neck of a bottle as in the cut, or better still, by slitting the tube a little way so that half the tube may extend an eighth or three-sixteenths of an inch over the lip, but care must be taken that it does not project too far.



A pair of octave tuning forks will also be needed. The large forks on resonance cases (to be had of any physical instrument dealer at a cost of from $5.00 to $20.00 according to pitch) are much to be preferred, because they sound longer after once being struck, but are not indispensable. A pair of octave forks can be made from an a' and a c'' fork by filing the a' till it gives c'. Choose an a' fork with thick and heavy prongs and file it in the crotch and along the lower half of the prongs inside, distributing the filing so as to leave the prongs of equal thickness, till it begins to beat with c'' when both are struck and have their stems pressed against the table. Then continue the filing carefully till the beats can no longer be heard. The filing warms the fork and makes it a little flatter than when cold; this of course must be taken into account. To make a c''' fork, if one is desired, a c'' should be used and the cutting must be at the free end of the prongs. In one made here about three-quarters of an inch was taken off. The tuning is as before by filing until the beats with c'' are first heard, then grow slower and finally disappear. In the same way an a'' may be made as the octave of a', but these small forks do not vibrate very long.

75. Beats. When tones not too greatly different in pitch are sounded at the same time they mutually interfere and make the total sensation at one instant more intense and the next instant less intense. This regular variation in intensity is called "beating." Exs. 67 and 70, where beats have been used incidentally, are a sufficient introduction to them. *a*. The rapidity of beats depends on the difference in the vibration rates of the beating tones. Prepare two bottle whistles of the same size and blow both at the same time. Slow beats will probably be heard. If not, pour a little water into one bottle (thus raising the pitch of its tone) and blow as before. Continue adding water a little at a time till the beats lose themselves in the general roughness of the tone. Blow the bottles separately now and then to observe the increasing difference in pitch. The same may be shown with a couple of piston whistles, if they are first adjusted to unison and then the piston of one or the other is slowly pushed in or pulled out. *b*. The rate at which the roughness of rapid beats disappears, as also the rate which produces the greatest roughness, differs with the pitch of the beating tones. Sound the following pairs of tones which have somewhat near the same difference in vibration rates per sec., namely, 33; and observe that the roughness from the beats decreases and finally disappears entirely at about the fourth pair: b' c'', c' d', e g, c e, G c, C G. The a' and c'' tuning forks give a vanish of roughness, representing a rate of 80-88 per sec.

Cf. Helmholtz, *op. cit.*, pp. 159-173; Stumpf. II, 449-497, especially 461-465.

76. Beats betray the presence of very faint tones both because the total stimulus is actually stronger in the phase of increased intensity and because intermittent sensations are themselves more effective than continuous ones. *a*. Strike a pair of beating tuning-forks and hold one at such a distance from the ear that it is very faint or quite inaudible. Then bring the other fork gradually toward the ear and notice the unmistakable beats. *b*. Strike a tuning-fork and hold it at a distance as in *a*, being careful to have the fork sidewise or edgewise, not cornering, toward the ear. Rotate the fork one way and the other about its long axis and observe the greater distinctness of the tone, due in this case simply to its intermittence.

77. Beats are in general attributed to the tone that is attended to; in the absence of otherwise determining causes, to the louder tone, if there is a difference in intensity, to the lower tone, or to the whole mass of an unanalyzed compound tone (see introduction to Ex. 82). *a*. Set two properly tuned resonance bottles about a foot apart on the table. Strike two forks that beat and hold them over the bottles. While both are about equally intense it is easy by mere direction of the attention to make the beats shift from one to the other. *b*. Turn one of the forks about an eighth of a turn about its long axis, which will weaken its tone and observe that the beats seem to come from the other fork. By moving first one fork and then the other the location of the beats may again be made to shift at pleasure. *c*. Warm the c' fork in any convenient way, (holding it clasped in the hand will do.) This will flatten it somewhat. Strike it and the c'' fork and press the stems of both on the table at the same time, or better on the sounding board of the sonometer. Observe that the beats seem to come from c' fork unless it is very faint. *d*. Tune a string of the sonometer so that its third partial (or corresponding harmonic) beats slowly with the c'' fork. (On partials and harmonics cf. Exs. 82-85.) Strike the tuning-fork and hold it over a resonance bottle, or press its stem against the table at arm's length from the string. Then pluck the string and attend to its tone, the beats may seem to affect the whole compound tone of the string. But this will not happen if the tone of the string is analyzed or if the attention is directed to the fork. The same may be tried on the piano

by picking out from the mistuned c'' forks one that beats slowly with c'' on the piano. Strike the f key and hold it down; strike the fork and observe the beats as before.

Cf. Stumpf, *op. cit.* II, pp. 489-497.

78. Difference tones.[1] When two tones are loudly sounded at the same time there results (probably from supplementary vibration of the tympanic membrane and ear bones) a third tone of a pitch represented by the difference of the vibration rates of the two original or generating tones. These difference tones are easy to hear when they lie considerably deeper than the generators, when the latter are loud and sustained, and when they make a consonant interval, though the latter is not essential. A loud difference tone may itself take the part of a generator and produce yet another difference tone—a difference tone of the second order—and so on, though difference tones of higher orders are heard with difficulty even by skilled observers of trained ear. Difference tones are hard to hear on the piano and similar stringed instruments, because of the rapid decline in the strength of the generators. *a.* Repeat Ex. 75 *a* continuing to pour water into one of the bottles till the difference tone appears. At first the roughness of the beats and the difference tone may both be heard at once. Try the same with the piston whistles, first setting them at unison and then slowly pushing the piston of one in or out while blowing hard. The beats will almost immediately give place to a low difference tone which may be heard ascending through several octaves before becoming indistinguishable from the generators. The double warning whistles used by bicyclists give a fine difference tone, to which indeed they owe their deep and locomotive like quality. *b.* Difference tones are strong on reed instruments. Press the adjacent white keys of a parlor organ, or the harmonical, by twos, beginning at c and going up a couple of octaves. If there is difficulty in hearing the difference tone, sound the upper tone intermittently and listen for the difference tone at the instant of pressing the key. *c.* Sound c'' and d'' which should give C for a difference tone (594—528=66). Sound also d'' and e'' which should give the same (660—594=66). If, however, the tuning is inexact, as it is intentionally in the tempered tuning of keyed instruments, these difference tones will be somewhat different and may be heard to beat with one each other when c'', d'' and e'' are sounded at once. Notice that you do not get these beats when the tones are sounded in pairs. On the harmonical this difference may be brought about by sounding one of the tones flat by pressing its key only a little way down. The same thing may be shown with three piston whistles blown at once, by a little careful adjustment of the pistons. *d.* The location of difference tones. The location of these tones is sometimes influenced by the location of their generators, but under favorable circumstances they seem to arise in the ears or even in the head. This is strikingly the case, both for the blower and the listeners, with the difference tones produced with the piston whistles.

Cf. Helmholtz *op. cit.*, pp. 152-159; Stumpf, *op. cit.*, II, pp. 243-257. König, Quelques expériences d'acoustique, Paris, 1882.

79. Blending of tones. The degree to which tones blend with one another differs with the interval relation of the tones taken. It is, according to Stumpf, greatest with the octave, less with the fifth, less again with the fourth, slight with the thirds and sixths and least of all with the remaining intervals. Try on the instrument the extent to which the tones forming these intervals blend, also those forming intervals greater than an octave: double octave, twelfth, etc. *b.* The blending in-

[1] König distinguishes between "difference tones" and "beat tones." Both tones, however, generally have the same pitch and the older term for them has here been retained; strictly speaking, however, the "difference tones" heard in these experiments are "beat tones."

case of the octave is so complete under favorable circumstances as to escape the analysis of trained ears. Use two tuning-forks, one an octave higher than the other, on resonance cases or held over resonance bottles. Sound the forks, first the higher, then the lower. For a while the higher fork will be heard sounding in its proper tone, but by degrees it will become completely lost in the lower and a subject with closed eyes will be unable to say whether or not it yet sounds. Stop the lower fork or remove it from its resonance bottle and notice that the higher is still sounding. Notice the change in timbre (cf. Ex. 86) produced by the stopping of the higher fork—something like the change from the vowel O to the vowel U (oo).

On *a* cf. Stumpf, *op. cit.* II, pp. 127-218, especially 135-142, 353; for his experiments on the unmusical confirming his grades of blending cf. 142-173. On *b* cf. Stumpf, *op. cit.* II, pp. 352-356, and Helmholtz, *op. cit.* pp. 60-61.

80. Analysis of groups of simultaneous tones. Ease of analysis depends on a number of conditions, among others on the following. *a.* Analysis is easier for tones far distant in the scale. Compare the ease of recognizing the sound of the c'' fork when c' and c'' are sounded together, with that of recognizing c''' when sounded with c'. Compare also the ease of distinguishing c' and a' with that of distinguishing c' and a''. *b.* Analysis is made easier by loudness in the tone to be separated. Repeat Ex. 79 *b* sounding the c' faintly the c'' strongly. No difficulty will be found in keeping the latter distinct. *c.* Analysis is easier when the tones make intervals with little tendency to blend. Compare the ease of analysis of c' c'' and c' a' or a' c''. Also notice that the addition of d'' (octave of d', fifth of g', fourth below g'') to the chord g d' g' g'' produces a less striking change than the addition of b' (major third of g', minor sixth below g''). *d.* Analysis is easier with sustained than with short chords. Repeat the last experiment making the chords very short and notice that the difference made by inserting either d'' or b' is less marked. Cf. also Ex. 95.

Cf. Stumpf, *op. cit.* II, 318-361, also his experiments, 362-382.

81. The lower tone of a chord fixes the apparent pitch of the whole. *a.* Repeat Ex. 79 *b* and notice that when the c' fork is stopped the tone appears to jump upward an octave in pitch (i. e. it takes the pitch of the c'' still sounding); but when the c'' fork is removed the quality of the tone is changed but not its pitch. *b.* Strike the chord C c'' e'' g'' or G e' g' c'' and compare the effect upon the pitch of the whole mass of tone produced by omitting C or G alone with that of omitting any one or all three of the higher tones. See also the function of the lowest partial of a compound tone in fixing the pitch, noticed below.

Cf. Stumpf, *op. cit.* II, 383-392.

Compound tones which on casual hearing seem single tones but in reality are chords deserve special attention. The tone given by the C string of a piano is made up of at least C, c, g, c', e' and g' and generally other tones. The lowest tone of the group gives the pitch attributed to the whole and is known as the *fundamental*, the other tones as *over-tones*. In another way of naming them, the component tones are all *partial tones* or *partials*, the fundamental being called the *first* or *prime partial*, the next higher the *second partial* and so on. It should be observed that the *first* over-tone is the *second* partial tone, the *second* over-tone the *third* partial, and in general that the same tone receives as a partial tone a number one higher than as an over-tone. The vibration rates of the partial tones of a compound are generally once, twice, three times, four times, the rate of the fundamental, and so on. In some cases, however, *e. g.* in bells and tuning-forks one or more of the partial tones may have vibration rates not represented in this series and discordant with the

fundamental tone. In what follows, the regular series of partial tones is meant except where the contrary is specified.

On the physics and physiology of this matter and others treated in this and the preceding section cf. Tyndall, On Sound; Blaserna, Theory of Sound in its Relation to Music; Taylor, Sound and Music; Helmholtz, Sensations of Tone. The last is of course the great classic on all such matters; the next to the last is very simple and untechnical and perhaps the best for those approaching the subject for the first time.

82. Partial tones: Analysis with resonators. If resonators are at hand the demonstration of the partial tones will be easy. Sound on the instrument the tones to which the resonators are tuned, and notice that they resound strongly to these tones and less strongly or not at all to other tones adjacent in pitch. Then sound the tone to which the largest of the resonators is tuned, and try the rest of the resonators in succession. Notice that others also resound (at their own proper pitch), thus betraying the presence of the tones to which they are tuned, and thus the composite character of the tone under examination. Which resonators will "speak" will depend on the instrument used, reed instruments giving a long and perfect series, pianos and stretched wires a perfect series generally as far as the 9th or 10th partial, and stopped organ pipes a short series. If difficulty is found in knowing when the resonator is resounding, it will be found useful to apply it to the ear intermittently, alternating, for example, two seconds of application with two seconds of withdrawal.

83. Partial tones: Analysis by indirect means. *a.* By sympathetic vibration. This succeeds especially well with the piano. Press the *c* key and hold it down so as to leave its strings free to vibrate; then strike the *C* key forcibly and after a couple of seconds release it. The *c* strings will be found to be sounding. Repeat, trying *c-sharp* or *b* instead of *c;* they will be found not to respond. Repeat the experiment, substituting *g*, c' e' g', and c''; all will be found to respond but in lessening degrees. Other keys between *C* and c'' may be tried but will be found in *very* faint vibration, if at all. *b.* By beats. This will succeed best with a reed instrument, e. g., a parlor organ or the harmonical. By pressing the keys of the instrument only a little way down any of its tones may be sounded a little flatter than its true pitch and so in condition to beat with any other tone having that true pitch. Sound at this flattened pitch the over-tones of *C* in succession while *C* is sounding, and notice the slow beats that result. For verification sound other tones not over-tones of *C* and notice that the beats when present are much more rapid.

84. Partial tones: Direct analysis without special apparatus. The directions given here apply to the sonometer, but will be readily adaptable to any stringed instrument in which the strings can be exposed. It is easier to hear any partial tone in the compound, if the partial is first heard by itself and then immediately in combination with the rest. On strings this is easily done by sounding the partials as "harmonics." Pluck the string near one end (say about one-seventh of the length of the string from the end), and immediately touch it in the middle with the finger or a camel's-hair brush. The fundamental will cease to sound and its octave (the second partial) will be left sounding, as an "harmonic." With it sound also other even-numbered partials, but less strongly. Pluck as before and touch the string at one-third its length; the third partial will now sound out strongest, with the sixth, ninth, etc., more faintly. Thus by plucking the string and touching it respectively at one-half, one-third, one-fourth, one-fifth, one-sixth, one-seventh, one-eighth, one-ninth and one-tenth its length from the end, the series of tones corresponding to the 2d, 3d, 4th, 5th, 6th, 7th, 8th, 9th and 10th partials can be heard, each in large measure by itself. In getting the higher "harmonics" it will be found better to pluck nearer

the end than one-seventh, and in no case should the string be plucked at the point at which it is presently to be touched. (cf. Ex. 86 *b*.) To hear the partial tones when sounding in the compound, proceed as follows. Sound the required tone as an "harmonic," and then keeping the attention fixed on that tone, stop the string and pluck it again, this time letting it vibrate freely. The tone just heard as an "harmonic" will now be heard sounding with the rest as a partial. When the partial is thus made out, verify the analysis by touching the string again and letting the tone sound once more as an "harmonic." Try in this way for the partials up to the tenth; first for the 3d, 5th and 7th, afterward for the 6th, 4th and the 2d, which is the most difficult of all. It has been said that analysis is easier at night, (not alone on account of the greater stillness), when one ear is used, and that certain positions of the head favor certain partials.

85. Partial tones: Direct analysis without apparatus. Certain parts of a compound tone are sometimes so separated by their dissonance, intensity or pitch that they stand out with striking clearness. *a*. Strike a tuning fork on a hard surface and observe the high, ringing, dissonant partials. They fade out before the proper tone of the fork, and are heard best when the fork is not held near the ear. *b*. As the tone of a string is allowed to die away of itself, different partial tones successively come into prominence. Try with a low piano string, keeping the key pressed down while the sound fades, or on the sonometer. Something of the same kind, but less marked, happens in the dying away of a low tone on a reed instrument when the air is allowed to run low in the bellows. *c*. When a tone is sounded continuously for some time, for example, on a reed instrument with one of the keys clamped down, different partials come successively into prominence, either through varying fatigue or the wandering of attention.

Cf. Helmholtz, *op. cit.* pp. 36–65; Stumpf, *op. cit.* II, 231–243, see also the index under *Obertöne*.

86. Timbre. The peculiar differences in quality of tones, (distinct from pitch and intensity,) which are known as differences in timbre (tone color, clang tint, *Klangfarbe*), are due to differences in the number, pitch and intensity of the partial tones present. Compare in this respect the dull-sounding bottle tones or the tones of tuning forks held over resonance bottles and the more brilliant tones of a reed or stringed instrument; the first are nearly simple tones, while the second have strong and numerous over-tones. *a*. Notice the difference in quality between the tone given by a tuning fork held before the ear and that given by the same fork when its stem is pressed upon the table. In the second position the over-tones are relatively stronger. *b*. Notice the differences in quality in the tone of a string when it is plucked in the middle, at one-third its length and at about one-seventh. When plucked in the middle, many odd-numbered partials are present and the even-numbered partials are either absent or extremely faint, and the tone is hollow and nasal; when plucked at one-third, the third, sixth and ninth partials are wanting and the tone is hollow, but not so much so as before; when plucked at one-seventh all the partials up to the seventh are present (for their theoretical intensities cf. Helmholtz *op. cit.* p. 79). *c*. Try also plucking very near one end, plucking with the finger-nail and striking the string with a hard body, e. g., the back of a knife blade; all these bring out the higher and mutually discordant partials strongly and produce a brassy timbre. Cf. also Ex. 79 *b*.

Cf. Helmholtz, *op. cit.*, pp. 65–119; Stumpf, *op. cit.*, II, 514–540.

87. In successive chords the whole mass of tone seems to move in the same direction as the part that changes most. Strike in succession the chords *e′ g′-sharp b′ e″*, *a a′ c″-sharp e″* or *a c′ e′ c″*, *a c′ f′ c″*. If the attention is directed to the bass in the first example and to the alto

in the second the whole mass of tone will appear to descend in the first case and to ascend in the second. If the attention is kept on the soprano part the illusion will not appear, as also when the observer examines his sensations critically. Cf. also Ex. 77 *d* where beats of a partial tone are attributed to the whole compound tone.

Cf. Mach, Analyse der Empfindungen, 1886, 126–127; Stumpf, *op. cit.*, II, 393–395.

88. Simultaneous tones interfere somewhat with one another in intensity.

a. Play the groups of notes numbered 1, 2 and 3 and observe the slight increase in the apparent intensity of the remaining tones as one after another drops out, making 1 sound like 1a, 2 like 2a, and so on. On the piano it will be well to play the notes an octave or two deeper than they are written.

b. Play the notes marked 4 and notice that the increase of loudness seems to affect the note (highest or lowest) that receives particular attention, making the effect in one case like 4*α*, in the other like 4*β*.

Cf. Mach, *op. cit.* 126; Stumpf, *op. cit.*, II, 418–423.

89. Consonant and dissonant intervals. *a*. The consonant intervals within the octave are the unison, octave, fifth, fourth, major sixth, major third, minor third, minor sixth. They will be found to decrease in smoothness about in the order given. Try them beginning with the octave and at *c*, as follows: *c c′*, *c g*, *c f*, *c a*, *c e*, *c e-flat*, *c a-flat*. Try the last four intervals also in the octave of *c″* or *c‴* and notice that they are less rough than when taken in the octave of *c*. Any other intervals within the octave are dissonant. Try *c c-sharp*, *cd*, *cb*, *cb-flat*, *c f-sharp*. The roughness is due to beating partial tones and in general is greater when these stand low in the series and are loud, and when they lie within a half-tone of each other. Work out for the tones of several of the intervals the series of partial tones up to the eighth. In general the extension of intervals into the second octave (taking the higher tone an octave higher or the lower tone an octave lower) does not change the fact of consonance or dissonance, though it may change the relative roughness. *b*. Those fitted by musical training to pronounce upon questions of consonance and dissonance hold that dissonance can be perceived between simple tones under conditions that exclude beats, and that consonance is not simply the smooth flowing of tones undisturbed by beats. The test is easy to make—simply to hold tuning forks making the intervals to be tested one before each ear, and if there are beats to carry the forks far enough away in each direction to make the beats inaudible—but only those of musical ear can pronounce upon the result.

Cf. on *a*, Helmholtz, *op. cit.*, pp. 179–197. Stumpf, *op. cit.* II, 470, 480. Wundt, Physiologische Psychologie, I, 439, II, 47 ff.; Mach, *op. cit.*, 129–130.

90. Consonant and dissonant chords. In order to form a consonant chord all the intervals between the tones used must also be consonant. The only chords of three tones which fulfil this condition within the octave are represented by the following: Major *c e g*, *c f a*, *c e-flat a-flat*, minor *c e-flat g*, *c f a-flat*, *c e a*. Try these and for comparison any other chord of three tones having *c* for its lowest tone.

Cf. Helmholtz, *op. cit.* p. 211 ff.; Wundt, *op. cit.* II, 61, 67 ff.

91. Major and minor chords. Compare the chords c'' e'' g'' and c'' e''-*flat* g''. This unmistakable difference in effect depends in part at least on the fact that in the major chord the difference tones of the first order are lower octaves of c'' itself, while in the minor chord one difference tone is not such at all and if taken in the same octave with the chord would be highly dissonant. For the major chord, when taken in the octave of c'', the difference tones are *c* and c'', for the minor chord *c*, *e-flat*, *A-flat*. Try on a reed instrument the difference tones generated by c'' e'', e'' g'', c'' e''-*flat*, e''-*flat* g'', first separately; and then while c'' and g'' are kept sounding, strike e'' and e''-*flat* alternately.

92. Cadences. Modern music requires the prominence of the key note or tonic and of the chord in which it holds the chief place at the beginning of a piece of music and at the end. The feeling of the appropriateness of this close and especially of the succession of chords in the following cadences can hardly fail to appeal even to the unmusical.

Cf. Helmholtz, *op. cit.*, 293.

BINAURAL AUDITION AND THE LOCATION OF SOUNDS.

Apparatus. In addition to apparatus already used, a pair of unison tuning-forks on resonance cases will be needed in Ex. 96 *d*, (and in several of the other experiments such large forks, unscrewed from their cases, are almost indispensable, because the tones of ordinary small forks are too faint and last too short a time), also a mechanical telegraphic "snapper-sounder," a yard-stick and a retort stand. The "snapper sounder," common as a toy a few years ago, can be bought of E. S. Greeley & Co., 5 & 7 Dey St., New York, at from 30 to 75 cents.

93. Unison tones heard with the two ears. *a.* Strike a pair of unison forks that will sound equally loud and vibrate an equal length of time, and hold one before each ear, three or four inches away; a single tone of rather indefinite location will be heard. As the forks are brought nearer, their tone seems to draw by degrees toward the median plane; and when they are very loud and near, the tone may seem to be in the head. Return the forks to their first position and then move one a little nearer or a little farther away, and notice that the sound moves to the side of the nearer fork. When the difference in distance has become considerable that fork alone will be heard. *b.* Bring the forks again into the positions last mentioned—one near and one far, (or better, place one fork on a rubber tube one end of which has been inserted in

the opening of the ear and hold the other fork before the other ear), and then with the free or more distant fork make slow rythmical motions toward and away from the ear, or rotate the fork slowly about its long axis, attending meantime to the fork on the other side. Alternate variations in the intensity of the tone of this fork corresponding to the approach and recession of the other and apparently unheard fork can be heard. *c.* Repeat *b* and notice that when the changes in intensity are considerable there is a simultaneous shifting of the place of the tone, toward the median plane when the tone grows stronger, and away when it grows fainter. These changes of place are, however, less marked than changes in intensity and those accompanying slight changes in intensity generally escape observation.

Cf. Schaefer, Zur interaurealen Lokalisation diotischer Wahrnehmungen, Zeitschrift für Psychologie, I, 1890, 300-309; also Silvanus P. Thompson, On Binaural Audition, Phil. Mag. Series 5, IV (July-Dec., 1877) 274-276; VI (July-Dec., 1878) 383-391, XII (July-Dec., 1881) 351-355; On the Function of the two Ears in the Perception of Space, XIII (Jan.-June, 1882) 406-416; and the references given by these two authors.

94. Beats heard with the two ears. *a.* Operate as in Ex. 93 *a*, with forks beating three or four times a second. *b.* Try with a pair of very slow beating forks (once in two or three seconds). Notice a shifting of the sound from ear to ear corresponding to the rate of beating. *c.* Try again with a pair of rapid beating forks (twenty or thirty a second) and notice that the beats are heard in both ears.

Schaefer, *op. cit.* also Ueber die Wahrnehmung und Localisation von Schwebungen und Differenztönen, Zeit. f. Psy. I, 1890, 81—98.

95. Difference of location helps in the analysis of simultaneous tones. Compare the ease with which the tones of a pair of octave forks are distinguished when the forks are held on opposite sides of the head with the difficulty of analysis in Ex. 79*b*.

Cf. Stumpf, *op. cit.* II, 336, 363.

96. Judgments of the direction of sounds. These depend in general on the relative intensity of the sounds reaching the two ears, but there is pretty good reason to believe that other things co-operate and that tolerably correct judgments, both as to distance and direction, can sometimes be made from the sensations of one ear. *a.* Let the subject be seated with closed eyes. Snap the telegraph snapper at different points in space a foot or two distant from his head, being very careful not to betray its position in any way, and require him to indicate the direction of the sound. Try points both in and out of the median plane. Observe that the subject seldom or never confuses right and left but often makes gross errors in other directions. Constant tendencies to certain locations are by no means uncommon. *b.* Have the subject hold his hands against the sides of his head like another pair of ears, hollow backward, and try the effect upon his judgment of the direction of the snapper. *c.* Find approximately how far the snapper must be moved vertically from the following points in order to make a just observable change in location: on a level with the ears in the median plane two feet in front; opposite one ear, same distance; in the median plane behind the head, same distance. Find the just observable horizontal displacements at the same points. A convenient way of measuring these distances is to clamp a yard-stick to a retort-stand, bring it into the line along which measurements are to be made and hold the snapper over the divisions of the stick. Snap once at the point of departure, then at a point a little way distant in the direction to be studied; again at the first point, so that the subject may keep it in mind, and then at a point a little more distant, and so on till a point is finally found which the subject recognizes as just observably different. Repeat, alternating snaps at the point of departure with those at a greater distance than that just found, decreasing the latter till a point is found where the directions can be no longer distinguished. Make a number of tests each way and take their average.

d. Continuous simple tones are very difficult to locate. Place a tuning-fork on its resonance case at some distance in front of the subject (seated with closed eyes), another at an equal distance behind him. With the help of an assistant strike both forks and after a little have one of them stopped and the mouth of its resonance box covered. Require the subject to say which has been stopped. His errors will be very frequent. Compare with this his ability to distinguish whether a speaker is before or behind him.

Cf. on *a* Preyer, Die Wahrnehmung der Schallrichtung mittelst der Bogengänge, Pflüger's Archiv, 1887; also v. Kries, Ueber das Erkennen der Schallrichtung, Zeit. f. Psy. I, 1890, 235-251. On *c* cf. Münsterberg, Raumsinn des Ohres, Beiträge zur experimentellen Psychologie, Heft. II, 1889. Rayleigh, Nature, XIV, 1876, 32.

97. Intercranial location of sounds. *a.* Sounds originating outside the head are not located in the head when heard with one ear. Hold a loud sounding tuning fork near the ear or place it on a rubber tube, one end of which is inserted in the opening of the ear, and notice that the sound when strong may be located in the ear, but does not penetrate further. Insert the other end of the tube in the opening of the other ear and repeat. The tone if loud will appear to come from the inside of the head. Removing and replacing the fork several times will help to give definiteness to the location. *b.* Repeat the experiment, but use a fork sounding as faintly as possible (*e. g.* set in vibration by blowing smartly against it), and notice that the location when a single ear receives the sound is not so clearly in the ear, and, when both receive it, not so clearly in the head, perhaps even outside of it. Cf. also Ex. 98 *b.* These experiments may also be made with beating tones instead of a single one.

Cf. Schaefer, *op. cit.* under 94.

98. Location of the tones of tuning-forks pressed against the head. *a.* Strike a large and loud sounding tuning-fork and press its stem against the vertex. The tone will seem to come from the interior of the head chiefly from the back. While the fork is in the same position close one of the ears, not pressing it too tight; the sound will immediately seem to concentrate in the closed ear. Have an assistant manage the fork and close the ears alternately. Something of the same kind happens when a deep note is sung; close first one ear and then both and notice the passage of the tone from the throat to the ear and finally to the middle of the head. *b.* Have an assistant manage the fork and close both ears. Notice that when fork is pressed on so as to make the tone loud the intercranial location is exact, but when the pressure is relaxed and the tone is faint the location tends to be extracranial. *c.* Try setting the fork on other places than the vertex. Notice that in the occipital and parietal regions the sound appears in the opposite ear. *d.* Take a long pencil in the teeth like a bit and rest the stem of a tuning-fork vertically on it near one end and close the ear on the other side; the sound will seem to be located in the closed ear. Then gradually tilt the fork backward toward a horizontal position, keeping it in contact with the pencil till its tip is opposite the open ear. The tone will change its place from the closed to the open ear.

On *a* and *b* cf. Schaefer, *op. cit.* under 94; on *c* cf. Thompson, second article referred to under 94.

PSYCHIATRY.

Psychoses Following Acute Surgical and Mental Affections and in Multiple Neuritis.

By William Noyes, M. D.

Introductory Note. Comparatively little attention has been given to the mental condition in this class of affections, and the importance of the subject suggests the advantage of presenting at some little length the more recent opinions of different writers. It is the description of the mental state of patients suffering from the disorders to which attention is especially directed, and there can be but little doubt that it would be a great gain to psychiatric nomenclature if Prof. Wood's title of *Confusional Insanity* could be generally adopted. Under such circumstances, "Confusional Insanity Following Typhoid," or "Confusional Insanity after Hysterectomy," would designate a distinct clinical entity and would occupy as proper a place in statistics and classifications as "Dementia Secondary to Mania." Prof. Wood's description of the mental state is a peculiarly graphic and vigorous one, and merits a permanent place in literature. It will be noted that Wood and Korsakoff takes opposite views as to the etiology of affection, for Korsakoff states that his *cerebropathy* occurs also after exhausting diseases, so that he and Wood are evidently describing the same affection. The occurrence of the affection in multiple neuritis, a distinctly toxic disease, goes far towards bearing out Korsakoff's views, and yet Wood's arguments against the toxic origin after acute surgical affections certainly have much weight. While, then, we may not at present look on the etiology as settled, there will be much gained if a distinct clinical picture can be agreed upon.

Insanity after Acute Surgical or Medical Affections. H. C. Wood, M. D. University Medical Magazine, December, 1889.

The author deprecates a tendency in writers on Insanity to recognize as distinct diseases several varieties of mental disorder, which he thinks should be viewed simply as symptom groups. The evidences of mental disorder may vary when the brain lesion is apparently the same, so that an individual case may appear to belong now to this and now that special insanity. Congestion, even active congestion, may go hand in hand with exhaustion, and failing nutrition even predisposes to local affluxes of blood, by producing weakness of the vessels, and according as now this and now that region of the brain is invaded by these local changes in circulation, so will the symptoms shift from day to day. The fact that two cases for a time prevent similar manifestations is no proof that they are essentially the same in their underlying cerebral condition, and the circumstance that they offer diverse symptoms is no proof that they are essentially unlike.

Wood believes that although insanity following acute disease varies greatly in its symptomatology, that in almost all the cases there is one common fundamental brain condition and that this fundamental brain condition bears no specific relation to the disease which has produced it, but may be the outcome of an altered nutrition produced by an exanthematous disease, like typhoid fever, or by a diathetic disorder, like rheumatism, by an accidental traumatism, or by a surgical operation. There are etiological and symptomatical reasons for believing that these insanities after acute disease are identical in their nature.

Etiological. If we believe that the insanity has a specific relation to the poison of the disease which it has followed, we must consider that there are at least a half dozen specific insanities connected with acute diseases, a very improbable supposition. The symptoms develop at a

time when the specific action of the poison upon the nervous system has exhausted itself, namely, during convalescence. The insanities develop after diseases or affections in which there is no known specific poison, such as childbirth, traumatism. surgical injuries, fevers, etc., which are followed by insane outbreaks, have one influence in common, i. e., they all tend to exhaust or impair the nutrition of the nerve centers, and it is known that impairment of the nutrition of the centers by lack of food combined with anxiety is capable of causing symptoms similar to those which are present in insanities developed after disease.

Symptomatical. Though the cases vary much in their details, the general scope of the symptoms and the general course of the disorder aie identical. There is always mental confusion, a mixture of excitement and mental power; and the cases nearly always end in complete recovery from organic disease.

Wood compares this condition to Krafft-Ebing's "Stupor; or Primary Curable Dementia," which is a condition of cerebral exhaustion in which there is almost complete paralysis of the mental functions with loss of nerve-tone in every portion of the body, so that the patient remains in a condition of more or less profound stupor or stupidity, with shifting or kaleidoscopic anomolies of motor and vaso-motor innervation, and at times also gives evidences of delirium, or of hallucinations. This primary dementia may be produced by starvation, by profound emotional shock, by diseases of the basal blood vessels, and it is asserted even by injuries to the head (?). If old age, syphilis or gout has produced excessive degeneration in the cerebral blood vessels, or if an emotional shock has been so severe as to permanently alter the nutrition of the cerebral nerve-cells, this so-called "Curable Dementia" may be an incurable affection.

Krafft-Ebing also recognizes under the name of *Wahnsinn* an affection which has been known to English and American writers as "Delusional Stupor," "Mania Hallucinatoria," "Confusional Insanity," etc., in which there is active delirium associated with an extraordinary abundance of hallucinations present in every sense region, and with a great weakness of the whole nervous system, as shown by pronounced loss of mental power almost amounting, it may be, to imbecility, by a tendency to stupor, by lack of muscular power, and by failure of nerve-tone in every portion of the organism. Krafft-Ebing considers that the two affections, *Wahnsinn* and Primary Curable Dementia clinically grade into one another, and that the underlying brain affection is similar in each affection. Wood believes that these two so-called diseases are merely diverse manifestations of one and the same pathological condition, and that they should be considered as one disease, and he suggests that the name *Confusional Insanity* be given to the condition because it is already familiar to many, has no pathological import, and expresses a symptom which is not only common to all forms of the disease, but is a necessary outcome of the pathological state.

In various chronic diseases attended with great bodily and mental exhaustion, the brain tissue gradually passes into a condition of perverted and exhausted nutrition similar to that of Confusional Insanity. In long drawn out cases of consumption there is often a gradual impairment of the intellect, associated with a super-activity of the imagination, and especially during the night the patient becomes delirious. Almost every history of shipwreck, followed by long exposure and starvation, affords examples of failing mental power, accompanied by increasing activity of the imagination, until desire and thought-pictures give rise to hallucinations, which are at first recognized by the sufferer to be false, but finally lure him to leap overboard.

The underlying nerve condition in each of these cases is one of a peculiar exhaustion, and it would appear tnat almost any form of acute

exhausting disease may be followed by a similar mental state. Wood has reported a case of so-called acute gouty insanity which he considers represented primary dementia, the stupor form of confusional insanity, and to his mind gouty and rheumatic insanity are probably almost always representatives of this disease.

Confusional insanity follows typhoid fever not very infrequently, and probably constitutes the bulk of the cases commonly named puerperal mania. To it, also, belongs the so-called surgical insanity. Within one year Wood saw it develop after ovariotomy, perineorrhaphy, and after the removal of the breast for cancer. It may also be due to emotional strain, especially when this is sudden or accompanied by exhausting circumstances.

In the mildest cases of mental disorders after acute exhausting disease the only symptoms may be enfeeblement of the general mental powers. In many cases the original mental constitution is recovered very slowly, being possibly slower in mild than in severe cases. This mental enfeeblement may be associated with depression of spirits, but this is not so intense or so overpowering as in melancholia, and the emotional disturbance is not the dominant element in the case. When confusional insanity is fully developed there is almost invariably a general lack of nerve-tone, as shown by a feeble circulation and coldness of the extremeties, by general muscular relaxation, and by failure of the digestive power. The temperature varies in different cases. It may be normal, but in severe cases there is usually either an habitually low temperature or a marked tendency to paroxysms of sub-normal temperature. On the other hand there may be a very distinct febrile reaction, especially seen in puerperal cases. The temperatnre curve is often remarkably irregular. The mental symptoms may seem to be contradictory, since many of them are those whieh are commonly believed to be the outcome of paralysis of cerebral functions, and others are such as are sometimes thought to be evidence of excited, though perverted cerebral activity. In the first group belongs that depression of consciousness, which in its mildest forms may be shown only by a peculiar quietude and by apathy, but which in varying degrees of greater severity manifests itself by stupor, ever growing, as the disease becomes more severe in intensity, until it deepens into a complete, persistent loss of consciousness. Another outcome of cerebral weakness is the peculiar mental confusion which is the most characteristic manifestation of the disease. It may reveal itself chiefly in the inability of the patient to talk coherently and persistently, words dropping out of the sentence or being uttered imperfectly, because the mind is unable to get the right word, ideas changing in the middle of a sentence, because the power of confining the attention to one consecutive line of thought is lost, so that the attempt at conversation on the part of the patient results in a jumble of half sentences, clauses and words, hopelessly intermixed with one another. Even, however, in mild cases of disease, the mental confusion usually manifests itself not merely in the inability of the patient to hold a connected conversation, but in his want of power to appreciate persons and things about him. In the most extreme instances no objects or faces are recognized, and even in the very mild forms of the disorder the patient may recognize some of his friends, yet be unable to place himself, insisting that he is away from home, and pathetically begging to be taken to his own house. The confusion of the patient is not altogether the outcome of pure mental weakness, but is usually in part due to the extrordinarily numerous and vivid hallucinations which affect all the senses, and compete for recognition, by the consciousness, with impulses which really originate in external objects.

The delirium is commonly mild and lacking in aggressiveness, but it may take on a vary active form, or the patient may be habitually quiet

but subject to paroxysms of fury resembling those of acute mania. More commonly, however, underlying even the aggressiveness and violence, there is a foundation of fear which often resembles that of delirium tremens, and when with this condition of fear there is associated distinct tremulousness, the likeness to delirium tremens is very pronounced; indeed, Wood believes that delirium tremens should be considered a form or variety of confusional insanity.

Very rarely ought there to be any trouble in recognizing the true nature of confusional insanity. The history of the attack, the knowledge that the outbreak was preceded by an exhausting disease, traumatism or emotion, the failure of bodily nutrition and of general nerve force, the lack of dominant emotional excitement, the stupor, the peculiar mental confusion, the kaleidoscopic character of the hallucinations, make diagnosis easy. The propiosis is favorable. Krafft-Ebing gets 70% of recoveries, and in Wood's cases even when the mental confusion has amounted to complete and absolute imbecility, complete recovery has almost invariably occurred, provided there have been no preëxisting organic bodily lesions, such as unsound kidneys, or degenerated arteries. Death may, however, occur in complicated cases. If the mental recovery be not complete, the result is lack of mental power, but never a so-called reasoning insanity, never a state resembling that of paranoia. Wood cites five cases illustrating his conception of confusional insanity: I., after childbirth; II., after removal of the breast for cancer; III., after perineorraphy; IV., after typhoid; V., after loss of sleep from nursing, combined with anxiety. All the patients recovered.

Cases of Post-Febrile Insanity. WILLIAM OSLER, M. D. John Hopkins' Hospital Reports, 1890, II, 46.

This article is written to give illustrative cases of Wood's Confusional Insanity, where there is one fundamental brain condition, viz:—impaired nutrition with consequent exhaustion of the nerve centres. Osler refers to the articles by Shepard (Am. J. Med. Sciences, Dec., 1888), and T. Gaillard Thomas (Medical News, 1889), and reports five cases:

I. Pneumonia. Slow convalescence with development of hallucinations and delusions.
II. Typhoid fever; severe attack with much delirium. Mania during convalescence. Gradual recovery after four months.
III. Typhoid fever of moderate severity. Development of delusions during convalescence. Recovery after six weeks.
IV. Typhoid fever, mild attack. Gradual development of delusions. Slow, halting speech. Recovery.
V. Typhoid fever, severe attack. During convalescence development of delusions. Persistence of mental symptoms for ten weeks. Recovery.

Prognosis usually good. Of the seven cases seen by Osler five after typhoid and two after pneumonia, six recovered and the seventh seemed likely to recover. Patients should therefore be cared for at home if possible. Seclusion, incessant watchfulness, absolute rest in bed, with massage and careful feeding are indicated. In the cases where the temperature is mentioned this had fallen to normal before the mental symptoms came on.

Osler does not attempt to add to Wood's description of the mental state of these patients.

Acute Confusional Insanity. CONALLY NORMAN. Dublin Journal of Medical Science, 1890, I, 506.

Norman claims that this form of insanity is not recognized in England. He agrees with Salgó that acute confusion is the most common of all forms of insanity, although Salgó's definition is too wide according to Norman. It would come between the acute mania and acute

primary dementia of Pinel. It is a condition of mental disturbance of comparatively rapid onset, characterized by dream-like engagement of consciousness and a tendency to abundant hallucinations of one or more senses. As the confusion or the hallucinations predominate the case resembles acute dementia or mania (melancholia.) Predominance of confusion corresponds to the delusional stupor of Newington; predominance of hallucinations corresponds to Mendel's hallucinatory mania. Norman finds hallucinations less frequent than other authors, and quotes Meynert as giving up the term acute hallucinatory insanity (Wahnsinn) for confusion. It is acute in onset; in form, acute or peracute, more frequently sub-acute. True chronicity hardly exists, except in uncured cases lapsing into secondary mania. Usually begins with hallucinations. Recovered patients speak of a dreamy obscuration of the mind; this frequently escapes observation. Consciousness profoundly affected; unoriented; confused as to time; varying and disconnected delusions flit through the mind, which are accepted as we accept dreams. Hallucinations may be pleasant or the reverse, following the emotional state of the patient. Emotional state generally indifferent, without pleasure or pain. Emotional condition variable as distinguished from mania or melancholia, sometimes gay, sad, anxious, angry, tender, or all these things together or in most rapid succession. Emotional disturbance is a reactive one, arising from the nature of the hallucinations. Acts as well as feelings are dictated by hallucinations. Episodic reactive states of emotional excitement or motor restlessness are apt to be followed by periods of increased confusion, deepening into stupor, or stuporous conditions intervene directly. Agrees with Krafft-Ebing that acute confusional insanity is essentially a condition of brain exhaustion, and probably due to brain anaemia or malnutrition of cortex. Patient is usually feeble and anaemic, or has recently suffered from some exhausting disease. This is more often than any other the form of psychical disorder associated with diseases not primarily affecting the nervous centres. Puerperal insanity is generally of this form, and the same of the insanity of rheumatism, and the delirium of fevers occasionally passes directly into acute confusion. Prolonged lactation, chronic suppurative affections, diseases of the stomach and of the lungs, especially phthisis, have a strong predisposing, if not exciting influence. Krafft-Ebing describes it as arising in prisoners. Norman has found it associated with nostolgia. Also occurs in cases of sexual excess or irregularity, generally with hallucinations. One case followed mental shock; and it is to be noted that the most common form that insanity takes when it follows sudden shock is the kindred one of acute dementia. Norman considers the well marked form of insanity following drink as acute confusional insanity, which is usually described as something between *delirium tremens* and acute mania. There is loss of orientation, dream-like impairment of consciousness, and numerous hallucinations. Dreamy confusion is more common in women. James Ross has described a confusion characteristic of dementia accompanying alcoholic neuritis. Wigglesworth confirmed Ross's observation, and in 1887 Korsakoff described in connection with alcoholic neuritis a "form of confusion with extremely characteristic mistakes in relation to space, time and situation." The onset is often acute. The insanity which comes "out of sleep" is always of this type. This brings it into line with that state occasionally present in the sane and especially in those of neurotic tendency and in epileptics, called by Germans *Schlafkrankheit*. Duration may be short, lasting only a few days or a few hours in abortive cases (as in some cases of menstrual disturbance), as Krafft-Ebing points out. Krafft-Ebing puts his recoveries at 70%. Cases which are about to recover occasionally pass into a state resembling acute mania, first observed by Meynert, who thought that the functional hyperaemia accompanying the maniacal

attack brought on a tendency to cure by increasing the circulation of blood through the exhausted brain. A slight degree of stupor more frequently precedes recovery, as in convalescence from acute mania. A mixture of maniacal and stuporous conditions is less favorable, or a tendency towards histrionic and pathetic displays, or the occurrence of pseudo-tetanic or pseudo-cataleptic states. Latter symptoms approximate Catatonia, which indeed is probably to be regarded as a variety of the general affection under consideration. As in all acute insanities death from exhaustion may occur in the early stage, and in debilitated sufferers there is a tendency to succumb to intercurrent affections. The diagnosis lies between acute mania, acute melancholia, acute dementia, and certain forms of paranoia. From mania it is distinguished by absence of exaltation and of increased rapidity of thought. (Norman, with Salgó, would exclude from mania any case with hallucinations). True emotional depression as a primary symptom is absent in acute confusion, distinguishing it from melancholia. It is intimately associated with acute dementia, and it is not always possible to say which form we are dealing with, though the presence of hallucinations and absence of complete stupor in a typical case of complete confusion sufficiently denote the ailment. Distinguished from paranoia by want of systematization of delusions, by existence of confusion, and by sudden mode of origin.

Norman repeats nine cases as follows:

I. Acute confusion, associated with alcoholic excess. Neuritic pains; recovery.

II. Acute hallucinatory confusion, associated with alcoholic excess; epileptiform seizures; recovery. "An extremely typical case of alcoholism in a woman."

III. Acute hallucinatory confusion associated with alcoholic excess.

IV. Confusion in the special form described by Ross and Wigglesworth occurring in a toper. Passage into secondary dementia.

V. Acute hallucinatory confusion resembling paranoia, associated with alcoholic excess. Recovery.

VI. Acute hallucinatory confusion simulating paranoia, following rheumatism and perhaps associated with nostalgia. Recovery.

VII. Hallucinatory confusion associated with phthisis.

VIII. Acute hallucinatory confusion dependent perhaps upon nostalgia. Passage into dementia.

IX. Acute hallucinatory confusion beginning in a dream. Apparent cause, sexual irregularity.

Norman cites Korsakoff's articles and considers that they are both describing the same form of mental disturbance.

Folie post-opératoire. PROF. MAIRET. Le Bulletin Medical, 1889; Aug. 28 and Sept. 1.

Prof. Mairet studies the mode of evolution of insanity following operations rather than the form of the insanity itself. He adds one case to literature, that of a woman of 42 who became insane three days after a laparotomy. Patient was intelligent and vivacious, but without hereditary or degenerative nervous taint. At 22, after childbirth, she suffered from attacks of hysteria with syncope, without absolute loss of consciousness, but with delusional troubles following, and hallucinations of sight and hearing; attacks sometimes lasted minutes, at other times hours; troubles appeared with menses. Intellect unimpaired, and she retained the management of her household. At 39 abdominal trouble appeared, necessitating laparotomy three years later. Three days after the operation began to laugh without motive and to have hallucinations of hearing. Delusions increased and patient admitted to asylum three months and a half after operation. Torpor and intellectual wandering

were most noticeable. Marked failure in nutrition. Refused to eat. Died of exhaustion 35 days after admission.

Mairet raises the question whether the sudden appearance of the mental trouble after the operation was simply a coincidence, or if the operation had a distinct etiological relation, and decides in favor of the etiological relationship. He finds in literature 24 cases where insanity followed operation, but admits that the list may not be complete. In analyzing these cases he finds that the rôle of the operation may be a variable one, being at times only an occasional cause, as in an operation in a case of alcoholism, while in other cases the operation plays a considerable part. There was considerable predisposition in his own case, while in a case reported by Herm-Lossen and Fuerstner the etiological importance of the operation was still greater, and the predisposition much less, there being no nervous predisposition except a chorea at the age of 14. In reviewing the cases Mairet reaches the conclusion that a certain amount of predisposition is always necessary, and that a surgical operation by itself is not capable of producing insanity. While the most different operations may be followed by insanity, are all operations susceptible in the same degree of producing it? It is the grave operations, especially those on abdominal viscera, that cause insanity without there being a strong predisposition. Werth reports the following results: Two cases of insanity in 32 hysterectomies, or 6%; two in 36 castrations, or 5.55%; and only two in 160 ovariotomies. Regarding the manner in which surgical operations produce insanity Mairet holds that in a surgical operation of considerable importance the surgical traumatism and its sequelæ are not the sole elements susceptible of working on the brain and thus developing insanity. For a certain time before the operation the patient is preoccupied; he dreads the operation, and his mind is in a state of tension that particularly favors the development of insanity. The anaesthetics, too, have a particularly strong action on the nervous system, and especially upon the brain. After the operation the surgeon uses in the dressings substances such as iodoform, which are in themselves capable of producing mental troubles; and finally, after the operation the patient must be excited by stimulants, particularly by alcoholic drinks. Mairet is convinced that insanity after operations is the result of these different causes, or at least of several of them. Although he attaches but slight importance to iodoform, he attaches much to the etiological influence of anaesthetics.

In cases where the predisposition is feeble it is necessary to go to the operation itself, as such, to explain the development of the insanity, but the published facts are too few to assist in ascertaining how the operation works. It is not so much the operation itself, properly so called, as it is that the traumatism is succeeded by a more or less extended and severe wound. In the cases reported the operation itself and its sequalæ have been absolutely regular. It is on the side of the nutrition that it is necessary to look for the reason of the action of the traumatism. In Mariet's case the troubles in nutrition appeared directly after the operation, but the observations are too few to say that this is always the case. This was markedly the case in Shepard's two cases. However this may be, the troubles of nutrition when they exist put the nervous system in a state of morbid receptivity which allows the passing delirium which the anaesthetics and the other causes may produce, to pass into a chronic state and to favor the production of true insanity.

As regards the time of onset of the mental disturbance, this may come on immediately after the operation, but generally it is not until several days, usually on the 3d or 5th day, or at least within the first week that the patient is perceived to be strange and to have lost his mental equilibrium. Sometimes, however, the mental troubles do not appear until later. Werth reports cases in the 2d, 3d and 5th weeks. Usually the

development takes place progressively—a modification of character and illusions appearing first, then agitation is added, and finally after a longer or shorter time, days or weeks, the insanity is definitely established. More rarely the insanity sets in suddenly without prodromes. Meredith reports a case where an acute melancholia appeared suddenly at the beginning of the 4th week.

Post-operative insanity has different forms, and here must be distinguished the cases in which the operation acts only as a provoking cause and those in which its pathogenic influence is considerable. When the operation plays only the rôle of an occasional cause the form which the insanity takes is dependent not on the traumatism but on the anterior state, which may be of a very variable nature. In one case it may be a very powerful predisposition or an intoxication, or in another case it may be a typhoid fever which modifies the central nervous system. When the pathogenic influence is most powerful the forms which are generally found are mania and melancholia, but the observations are too few to say if the mania or melancholia have a special physiognomy. [Wood's remarks on this subject seem to be of much greater value.]

As regards prognosis this depends largely on whether the operation plays the part of a primary or an occasional cause, being more grave where the antecedent predisposition is more marked, and where the nutrition is poor, and here leading to incurable insanity or to death.

In summing up the whole subject Mairet concludes:

1°. It is among the predisposed individuals, predisposed either by heredity or any other cause (alcoholism, infectious diseases, etc.), that surgical operations give rise to insanity.

2°. Among the constituent elements of an operation that may act on the brain the two most important from the point of view of the development of insanity are anaesthetics and surgical traumatism with their sequelæ, chief among which are the troubles of nutrition.

3°. When the predisposition is considerable the anaesthetics may of themselves alone set this into activity and cause the appearance of insanity, so that the less important operations, acting as surgical traumatism, may give rise to insanity.

These points should govern the conduct of the physician in interfering surgically in predisposed individuals. Among these individuals one ought not to undertake an operation of any consequence except when there is a vital necessity, and when it has once been decided upon, anaesthetics, at least general anaesthetics, should be omitted if possible. [It need scarcely be pointed out that Prof. Mairet goes to extremes that few or any would care to follow in ascribing such overwhelming importance to anaesthetics. Were anaesthetics withheld to the extent he advocates, from the remote possibility of mental disturbance, much needless suffering could not fail to result.]

Insanity followiug Snrgical Operations. LAWSON TAIT. British Medical Journal, Aug. 31, 1889. (Abstracted in Dublin Journal of Medical Science, 1890, I, 250.)

This is a criticism of the book of Dr. E. Denis on this subject. Tait says that he has performed between 7,000 and 8,000 operations, requiring the use of anaesthetics, and has had anaesthetics administered in cases not involving traumatism in 3,000 more instances, and he knows of only seven cases of sequent—not necessarily consequent—insanity. There may have been other cases, and he will say 14 cases to cover the margin of error. His own practice therefore does not yield a proportion of cases of insanity following operations larger than the general proportion of insanity in the female adult population, and including the cases of anaesthesia is probably considerably smaller. Dr. Denis gets an average of 2.5 cases of alienation in 100 operations. But if this had been the case

all engaged in active operating practice would have felt the fact long ago. Tait is struck by the occurrence of insanity after operations as being like the occurrence of tetanus, something to be met with occasionally, but not a matter to calculate on. He continues: "If I saw an insanity rate of 2.5% in my operations it would be more striking than any death rate in anything except my hysterectomies, and in that class I have never seen insanity follow a single instance; and Dr. Bantock's experience amounts to practically the same result, for his exception cannot really be called one of insanity following an operation. As a per contra I can point to 13 cases where operations have cured insanity."

Ueber Psychosen nach Augen-Operationen. Von FRANKL-HOCHWART. Jahrbuch f. Psych., 1889-90—IX, pp. 152-182.

The author reports 31 cases of psychoses developing after eye-operations. Divided into four groups, as follows:

1. Hallucinatory Confusional Insanity. (a) in young, (b) in old individuals.
2. Simple Confusional Insanity in old people.
3. Psychoses in chronic alcoholism.
4. Cases of Confusional Insanity in very marasmatic individuals, with other intercurrent somatic diseases with fatal termination.

The first group comprised 15 cases; lens extraction in almost all, began six times in the first 24 hours, twice after two, once each after three and four days, twice after several days, once after nine days, once after ten to twelve days, once after three weeks. There was a Protean-like change of phenomena in the different individuals; there was wild, unmanageable agitation, ideas of grandeur and insignificance, ideas of suicide, ceaseless cryings, praying, lamenting, and then laughing, dancing and singing, with passionate emotional displays. These more sharply defined prodromal symptoms belong more to youth; in older people there is unrest, confusion and tendency to aggression, and also terrible visual and auditory hallucinations. Disease is usually fully developed when the patient is transferred to the asylnm.

Regarding the course of these psychoses it can only be said that this is a very varying one. Some last a few days, and from that up to weeks, or to one, two or five months. One patient formed a complete delusional system of persecution after he had been three months in the asylum.

In the group of alcoholics there were seven patients, six of whom had cataract operations. Course offers little that is noteworthy; begins earlier than in non-alcoholics. Shows itself in restlessness and excitement. Course marked by unrest, hallucinations, conditions of anxiety, ideas of persecution, confusion, delusions. Course similar to delirium tremens. Lasts from 6 to 12 days to 4 weeks. Some dementia in one case.

In the first group (hallucinatory confusional insanity) hallucinations were the chief thing noted, with sharply defined delusions, here and there running into a system, while in the second group (simple confusional insanity in old people) the patients were simply confused and disturbed, hallucinations being absent. They were unoriented, did not know what had happened to them, were irritable, sometimes aggressive. They were all old, but not of the specific senile form. The same conditions are seen in exhausting conditions in youth and in alcoholics. All men, from 57 to 77. Cataract operations in all. Psychosis developed soon after operation; in none after sixth day. Unrest, anxiety, aggressiveness showed itself in the beginning. Prognosis not unfavorable. Of the last group there were only three cases. In all inanition, delirium and fatal termination.

Regarding the casual nexus the simplest explanation would be to put the cases among the psychoses following operations, as first pointed out

by Dupuyten, and in Germany by Wunderlich. There is no reason to doubt this casual nexus. Can call these affections nothing more than a specific symptom-complex, as Dupuyten has done. They generally take the course of hallucinatory confusional insanity. Rose thinks almost all psychoses following operations are to be considered as delirium tremens, and further that sepsis and high fever may form a substratum of the mental disturbance. Some psychoses developing with hallucinatory confusion he designates as inanition deliria. Von Frankl-Hochwart considers these psychoses relatively rare compared with those following eye-operations. In Vienna the last are much more common than the first.

Winiwarter speaks of psychoses after surgical operations as being especially rare. When Fuerstner reported the first case of insanity after a gynaecological operation he expressed surprise that the case should be so rare while they are so frequent after eye-operations.

Werth could collect only 34 cases of insanity after surgical operations. This disproportion is all the more striking when it is considered how many factors enter into surgical operations that seldom occur in eye-operations, such as the great pain before and after the operation, febrile phenomena, cachexia of cancer, disposition to tuberculosis often occurring in joint disease, inanition, etc. Surgical cases are often depressed in emotions, since they are to suffer the loss of some member, while eye-patients *per contra* have the hope of regaining their sight. The author collects 19 cases of psychoses after surgical operations, of which 3 were of delirium tremens, showing that insanity after surgical operations is comparatively rare in spite of the fact that besides the operation the other important etiological factors are so frequent. What is the special feature of eye-operations that psychoses so often follow them? That lesion of the sensitive optic nerves must be a tremendous irritation is clear *à priori*, and attention is called to the connection between irritation of the trigeminas (neuralgia) and psychoses. Psychoses have developed through simple injury to the bulb—(Griesinger, Arndt and Fürstner). That mental disturbances may arise through irritation of the sense-organs is indicated by the influences of ear diseases and by Esquirol's observation of insanity following a strong smell. According to our author's researches blind people have a special predisposition to mental disease, of predisposing moment in eye diseases is the psychical factor that loss of sight is especially feared [This does not agree well with author's previous statement that hope of regaining the sight was in the favor of these patients as against the fears of ordinary surgical cases]. Also in any of the cases that the oculist has to do with are of advanced age. Of greatest importance, however, appears to be the influence of darkness that is necessary in the after treatment, together with the absolute rest and the separation from the outer world.

Eine psychische Störung combinirt mit multipler Neuritis. (*Psychosis polyneuritica seu cerebropathica psychica toxaemica.*) Dr. S. S. Korsakoff. Allg. Zeitschr. f. Psychiatrie, 1889, xlvi. Bd., H. 4, p. 475.

Previous to the present article Korsakoff has published articles in Russian describing the disease, which he claims is little known to physicians, although numerous instances have appeared in the practice of alienists and also of gynæcologists. The disease is especially liable to develop after certain diseases, such as puerperal fever, acute and chronic infectious diseases. Korsakoff claims that this form of mental disease is unknown, and that there is no description of it in literature. In almost all cases the symptoms of multiple neuritis may be found, in some cases they are but little marked, in others the symptoms of nerritis, paralyses, contractures, muscle atrophies and pains are so predominating that they may cover up the mental disturbance. Besides the combination with the neuritic symptoms, the symptom-complex of the

mental disturbance is in itself characteristic, especially the disturbance of memory and of the association of ideas. All these things taken together give the disease so peculiar a stamp that it is incomprehensible to Korsakoff that it has not been described before, but he explains this by the fact that the disease occurs in the course of other diseases, and the attention of the physician is concentrated on these, and thus the complications on the side of the nervous system are overlooked. The beginnings of the disease are frequently difficult to recognize. Since it ordinarily develops as a complication of severe diseases such as typhoid, puerperal fever and the like, its initial symptoms are bound up with the usual weakness, exhaustion of the nervous system and anæmia of the brain. The beginning is usually ushered in by vomiting, sometimes very stubborn. Then considerable weakness develops. The patient staggers on walking, his gait is progressively unsteadier, finally he can no longer stand and must lie down. The paralysis of the lower extremeties now becomes noticeable, and the motions of the feet and toes are disturbed. The upper extremities, hands and fingers, are also frequently involved. Pains develop in the arms and legs, the muscles fall away considerably, the electrical contractility diminishes, contractures and sometimes œdema develop, and the patellar reflex ordinarily disappears early. In severe cases there may be complete paralysis of the extremities, the muscles of the back become paralyzed, likewise the bladder and diaphragm, and finally paralysis of the heart occurs through disturbance of the functions of the vagus. Parallel with these symptoms in which the multiple neuritis shows itself, there proceeds the development of the mental disturbance. These are less striking in the beginning and manifest themselves externally as simble irritibility or lowered activity of the nervous system referable to the general weakness. At first the patients appear very capricious and assuming, or on the contrary, very apathetic, and sleep in the way that much exhausted men are accustomed to do, but symptoms develop later that make it certain that the disease is not like an ordinary nervous weakness. These symptoms appear either in the form of excessive irritability and great unrest, or as outbreaks of acute mania with clouded consciousness, or again in the form of marked loss in the mental sphere and deep disturbance of memory. Careful examination of the mental symptoms reveals a multitude of peculiarities which are very significant for the diagnosis of this disease. The mental symptoms do not make their appearance in all cases in the same manner. In certain cases there is a greatly increased irritibility and excitability with consciousness well preserved; in other cases, on the contrary, consciousness may be confused, and there may be apathy or agitation, and finally in still other cases a characteristic disturbance of memory comes to the front, a special kind of amnesia. If the mental excitement consists in increased susceptibility and irritability, this is generally displayed in great excitability, unrest and vague fear. The patient fears death, an attack, or he knows not what; fears to remain alone, constantly calls to himself, sighs, or laments his fate. Not rarely the consciousness remains clear a long time, but in many cases after the first few days of excitement consciousness becomes confused. Patient mixes up words and cannot speak connectedly. Every day the confusion increases, patient begins to tell of all kinds of monstrosities, speaks of journeys that were never performed, mixes up old reminiscences with recent events, does not know where he is or what is going on about him; sometimes illusions of sight and hearing develop which still more confuse the patient. Thus the same patient is at times entirely quiet, at other times very restless. The disturbed periods usually come on towards evening, when the patient begins to be restless, becomes angry if he is not given what he wants; sometimes the restlessness reaches a very high degree. There may be attacks of raving, of acute mania. Sometimes these may occur in the

beginning of the disease, later the excitement may still exist, yet it may not break out in attacks, but is limited to singing songs the whole night through. Sometimes the disturbance of consciousness reaches a very high degree and may almost go to the complete loss of consciousness. With this there also goes a deep disturbance of memory. It takes the form of a peculiar amnesia, in which the memory for recent events is principally disturbed, while that for events long past remains very good. Generally such an amnesia develops after the excitement already described, with confusion of consciousness; this excitement lasts some days, then the patient becomes quiet, and his consciousness becomes clear, he begins at the same time to gain back his mental faculties, but his memory remains deeply disturbed. This especially shows itself by his asking the same question and repeating the same things. In the beginning the presence of a mental disturbance is hard to recognize in conversation; he gives the impression of a man who is complete master of his mental faculties, draws correct conclusions from given premises, plays cards and chess, in short, conducts himself like a mentally sound man, and only after a long conversation can one notice that from time to time the patient mixes up matters in an extraordinary manner, and does not remember what goes on about him, does not remember whether he has eaten, whether he has been out of bed. Many times the patient immediately forgets what has happened; some one comes to him and speaks to him, goes away for half a minute, and on his return the patient has no recollection that he has been with him. He may read the same page for an hour and have no recollection of what he has read. He may repeat the same things twenty times without being in the least conscious of the constant repetition of the storeotyped phrase. He cannot remember the persons with whom he comes into contact exclusively at the time of his sickness, although he sees them constantly, and every time he sees them he is sure that it is the first time.

The phenomena in which the amnesia is manifested differ in some degree according to the degree of the disease and the intensity of the disturbance. In the slighter degrees the memory for the more recent past is not completely lost but the events remain only vague, floating in memory. Often the patient recollects the affair itself but not the time when it took place; in other cases the forgetfulness concerns the peculiar thought-processes, in consequence of which the patient does not know what he has said, and continually asks one and the same question. Sometimes all the facts are present in memory, but the patient needs special conditions to bring them to consciousness.

On the other hand, in very severe cases the amnesia is much deeper, and the recollection is lost not only for recent events but also for earlier ones; it especially happens that the present momentarily disappears out of the patient's memory while events of years ago come to the front, and the patient mingles old reminiscences with new impressions of the present; he thinks himself in the same conditions as thirty years ago, and the persons about him to be those whom he knew at that time, who, perhaps, have long been dead. In the more severe forms the memory for events is completely lost, and even the word memory disappears; the patient forgets his own name and brings out unconnected sounds instead of the words. With the severe forms of amnesia there also ordinarily occurs a marked clouding of consciousness, which in the severest cases may amount to a condition of complete loss of sense. The amnesia has no stationary character, it may be greater or less. The variations in its intensity depend among other things on temporary conditions; by fixing the attention of the patient and securing his good will the memory is often better. Most frequently, however, the intensity of the amnesia naturally depends on the general course of the disease and on the depth of the general disturbance. Thus the amnesia

diminishes on the improvement of the disease, and may entirely disappear; but if the disease becomes worse the amnesia becomes deeper and deeper, and in addition to the symptoms of the amnesia a marked confusion is developed. This confusion comes out in slight degrees in this form of amnesia, but the confusion is not with regard to the impressions that the patient receives at the moment but only with the earlier events. To the question how he passes his time the patient often does not answer at all what is the case, but replies that he went to the city yesterday, whereas he has not left his bed for two months; he tells of imaginary visits, conversations, etc.; sometimes such patients invent a story and repeat this continually, so that a peculiar form of delirium develops having its root in pseudo-reminiscences.

These are in general the most characteristic features of the mental disturbance observed in patients suffering from this disease. By the side of the mental symptoms there go, as already said, the ordinary phenomena of degenerative multiple neuritis, such as paralyses of the lower, and sometimes also of the upper extremities. These symptoms are not always clearly defined; in many cases they are only indicated by insignificant pains in the legs and unsteady gait. The patellar-reflex does not entirely disappear, but is frequently increased, or remains normal. In addition there can always be found somewhere on careful examination the signs of neuritis, which thus assists in the diagnosis of the psychical disturbance. Besides the phenomena of neuritis there also ordinarily exists in this disease disturbances of the general organism. There is much emaciation, very frequently severe vomiting, diminished excretion of urine, which on this account appears reddish brown like strong tea. The phenomena of myositis are not rarely present. Sometimes the heart's action is disturbed and the pulse is irregular; at times dropsy develops; in women the menses stop; lower temperature develops. Besides the neuritis and the symptoms of disturbance in the hemispheres, other phenomena related to the brain and cord not rarely develop, such as disturbances of speech and swallowing, and sometimes opathalmoplegia externa, nystagmus and the like.

The course and termination of the disease depend on its intensity and the conditions under which it has developed. As already stated, the disturbance often comes on in the course of other diseases, acute or chronic; it is also not at all rare in chronic alcoholism, as well as common in the different intoxications. Not infrequently, for example, in alcoholism the disease may set in with symptoms which are entirely similar to delirium tremens, and subsequently there are joined to this the paralyses and the characteristic disturbance of memory. A similar beginning not rarely comes on in the course of puerperal diseases; an attack of panphobia suddenly breaks out with intense excitement, followed by confusion of consciousness, failure of memory and other symptoms.

In other cases in very weak patients the disease comes on unnoticed, without a sharply marked attack; a gradually increasing forgetfulness develops, and then confusion of consciousness is added to this, reaching the highest degree. The termination of the disease depends equally on its intensity and its mode of origin.

If the source of the disease is removed the termination is not infrequently a favorable one, recovery may set in, generally after a very long time, after several months, still oftener after some years. If, on the contrary, the source of the disease is not removable, if it is, for example, a disturbance that has developed on the basis of a tuberculous or carcinornatous cachexia the termination is for the most part an unfavorable one. The disease may also proceed to a fatal termination if it develops with great intensity in an organism which has only slight resistive power. Thus the beginning, course and termination of the disease,

stand in the most immediate relation to the etiology. The etiology is the same as that of multiple neuritis, and all the causes which may bring on multiple neuritis lead at times also to this form of multiple disturbance. As multiple neuritis comes on with special frequency in drinkers so this form of disease comes on very frequently in alcoholic neuritis and alcoholic paralysis.

The mental disturbance above described has received some attention by different writers, first by Magnus Huss, but no one saw in the mental disease anything peculiarly connected with the neuritis, but all held the psychosis to be simply a complication of the disease under the influence of alcohol. Korsakoff claims to have been the first to show that a completely analogous mental disturbance develops in cases of multiple neuritis where alcohol can play absolutely no rôle as an etiological factor, and he has published fourteen cases of multiple neuritis of non-alcoholic source with a clearly marked mental disturbance. These observations lead Korsakoff to conclude that this mental disturbance belongs to multiple neuritis and to ascribe its origin to the influence of the same pathogenic character which produce multiple neuritis. These conditions do not always appear to bring on the mental disturbance in the same degree as the neuritis, for in many cases the neuritic symptoms appear more marked because the pathogenic agent has worked more on the peripheral nervous system, while in other cases the mental symptoms predominate in consequence of the pathogenic agent influencing the brain by preference. In still other cases the cerebral and peripheral disturbances are marked in almost equal manner.

Turning to the etiology of the fourteen cases published by Korsakoff we find the sources of the disease to be very different, such as the presence of a dead fœtus, puerperal septicaemia, accumulation of feces, typhoid tuburculosis, diabetes mellitus, lymphadenoma, and the breaking down of a tumor. Adding to these that this form of disease also develops in alcoholism, poisoning with arsenic, lead, sulphuric acid, carbonic oxide, etc., we see that the sources of the disease are extremely varied. Still it is easy to see that there is something in common in them all, since in all these cases the composition of the blood is altered poisonous substances are accumulated in the blood, and it is in the highest degree probable that it is these which poison the nervous system, in individual cases the peripheral nervous system being puerperally affected, in other cases the central nervous system, but often both in the same degree. It is hard to say what these poisonous substances are, but in most cases they belong to the ptomaines or leucomaines, which have reached the organism from the outside or have developed in it under favorable conditions. Korsakoff has very properly named all of them *toxaemic cerebr opathies* (cerebropathie psychica toxæmica). They may also be called *polyneuritic* psychoses (psychocis polyneuritica), but it must be borne in mind that cases of this kind of mental disturbance may develop in which the symptoms of multiple degenerative neuritis may be poorly marked and thus may be overlooked. The pathological anatomy of the disease is still not sufficiently explained, but the presence of multiple degenerative neuritis may be looked on as proved.

Ueber eine besondere Form psychischer Störung combinirt mit multipler Neuritis. S. S. KORSAKOW, Arch. f. Psych., 1890, xxi Band, 3 Heft. p. 669.

The present article is mostly taken up with a consideration of the etiology of multiple neuritis, and the author refers to the fact that in the beginning of the year 1887 he advanced the theory that in addition to the poisons that get into the body from the outside and cause neuritis, this may also arise from poisons developing in the body itself—ptomaines and leucomaines. The views of Rosenheim and Leyden on the origin of

multiple neuritis are given, together with those of the French authors, Bouchard, Charin and Roger.

In any disease where the eliminative powers of the body are reduced we may get auto-intoxication from the accumulation of the ptomaines and leucomaines, multiple neuritis, and together with this Korsakoff's *cerebropathia toxæmica*. This has developed in glycosuria, in pyæmia, in tuberculosis, in pyæmia, and after typhoid, after the birth of a fœtus that had undergone decomposition; in this latter case there were absolutely no phenomena of putrefaction to be found on the genital apparatus but the disease had apparently developed directly through absorption of ptomaines in the blood. In the cases cited numerous instances are given which point to the abnormal constitution of the blood; one case developed in connection with leucocythæmia, another in a liver disease, a third with the breaking down of a neoplasm. Korsakoff would ascribe to the ptomaines or leucomaines resulting from the activity of the tubercle bacillus in tuberculosis the physical disturbance so frequently found in this disease, contrary to the view of Wood who would account for the disease simply by the great exhaustion produced. In view of all these facts Korsakoff calls the cerebropathy described a toxæmic cerebropathy, since he assumes that all cases of this disease stand in connection with some one toxæmia. In individual cases the fundamental toxæmia influences the peripheral nerves alone, in other cases it affects the cord, and in still others the brain. These latter cases being the ones in which the mental disturbance is produced. Why in the one case the affection is confined to the peripheral nerves while in another case the brain is a fellow sufferer is unknown. Apparently this depends on the affinity of the poison circulating in the blood, and in part on the dissimilar powers of resistance of the nervous system in different men. The fact that physical disturbance in question has been observed to be especially frequent in multiple neuritis of alcoholic origin may well be conditioned on the fact that the brain has become particularly susceptible through the drinking of alcohol.

The nature of the poison circulating in the blood also apparently has something to do with this difference, for while there is almost always a disturbance in alcoholic multiple neuritis, yet in the neuritis after diphtheria there is no known case where a psychosis has developed.

In his earlier work on alcoholic neuritis Korsakoff explains this excessive vulnerability of the brain through an apparent alteration of the lymph apparatus in general, and especially of the connective tissue, this alteration establishing itself in the nervous system in alcoholism, and in consequence each accumulation of toxic products in the blood or lymph leads much quicker to poisoning than in normal conditions. This explains why multiple neuritis and cerebropathies are especially frequent in the tuberculosis of drinkers, and also why in such cases neuritides and cerebropathies break out in consequence of strong emotions or marked physical exhaustion, the products of fatigue in such cases are not sufficiently eliminated through the lymph and act toxically on the nerve elements. If this is the case, then the designation of such forms of disease as *toxaemic* is not strictly correct since the direct source of the disease is to be looked for not in the blood but in the fluid saturating the tissue elements. In this appears to Korsakoff to lie the real objection to the name adopted by him, yet in default of another the title *cerebropathia psychica toxaemica* seems justified, and to characterize the disease and its genesis.

The article contains the minute clinical reports of six cases. The first that of a woman who gave birth to a dead child in which decomposition had already set in; secondly, an analogous case, the child being healthy but the after-birth being retained; in the third case psychosis followed typhoid; in the fourth case there was specific disease, abuse of

alcohol, malaria and lymphadenoma; in the fifth, probably retrogressive metamorphosis of a fibroma; in the sixth the etiology was doubtful, although alcohol may have had some influence.

The six cases were observed in two years. The first, third and sixth cases recovered, the other three died.

Ein Fall von polyneuritic Psychose mit Autopsie. S. S. KORSAKOFF UND W. SERBSKI, Arch. f. Psych., 1891, xxii Band, 1 Heft; 112-134.

The psychosis in this case followed a laparotomy for the removal of a dead fœtus in a case of extrauterine pregnancy. A septic fever developed before the operation, after which the temperature fell perceptibly, although it always remained high.

A week after the operation, in addition to the irritability manifested earlier, there was considerable excitement and a clearly marked weakness of memory for recent events. Consciousness was clear in the beginning, but soon began to be clouded, and at the same time symptoms of weakness in the extremities developed, the tendon reflex disappeared, and the symptoms of multiple neuritis developed.

Although the wound healed the affection of the nervous system increased; the disturbance of memory became more marked, the association of ideas was completely lost, from time to time there was excitement, and hallucinations developed. The paralysis increased, and extended to the upper part of the body, and the patient died from paralysis of the diaphragm. As in the previous cases Korsakoff attributes the disease to the poisoning of the central and peripheral nervous system by the ptomaines circulating in the blood. At the autopsy the characteristic degenerative changes of multiple neuritis were found. The phenomena of multiple degenerative neuritis were found in all the nerves examined with the exception of some cranial nerves. The muscles showed evidences of a degeneration of an irritative character—increased number of nuclei. In the brain nothing was found by the methods used, but Korsakoff thinks that the failure to find any changes in the brain was to be accounted for by the fact that the mental disturbance had existed in the patient only a relatively short time, and that the anatomical substratum of the disturbance did not have time to develop to a sufficient degree to become evident by the methods of investigation employed; possibly also because the cortex was not examined by all the methods.

Korsakoff does not think that the negative result justifies the assumption that the mental disturbances in multiple neuritis is unaccompanied by any changes in the cortex, but he is much more of the view that these changes exist in many cases, and cites as a proof that in his observations on alcoholic neuritis where a characteristic mental disturbance was present a change in the cortex was found, viz: alteration of the vessels, miliary extravasations, increase of the connective tissue and spindle cells.

Polyneuritis und Geistesstörung. ERNST FRANK. Inaugural Dissertation, University of Bonn, 1890.

Frank reports a case of mental disturbance, to which the phenomena of polyneuritis were added very early. The clinical picture is very similar to the psychoses described by other authors as occurring in multiple neuritis, although some of the symptoms usually present in these psychoses were absent in this case. The author quotes Korsakoff's description of the mental condition. Frank's case presented especially the peculiar disturbance of memory described by Ross. While in almost all cases of psychoses in multiple neuritis, as described by Korsakoff and others, there are still other phenomena, such as delusions, hallucinations, illusions, stupor, and even well-marked delirium tremens, yet these

according to Frank, only develop in alcoholic multiple neuritis, or in those cases which are due to infection or other form of intoxication. The question arises whether it is necessary to look for the origin of such disturbances in a pathological and anatomical change in the brain, as has been done by many, or if the outbreak of psychoses in multiple neuritis may be explained without such an assumption.

Tilling holds that such a direct and anatomically provable disease of the brain exists in consequence of the same injurious conditions which affect the peripheral nerves. Tilling's explanation, according to Frank, holds good only of cases of alcoholic polyneuritis, and whether in such cases such an explanation of the connection between psychical disturbance and mental disease may be disputed; at all events, autopsies made up to this time speak against this. Spinal changes, at least such as would correspond to the clinical phenomena, have never been found, not even in cases of alcoholic ataxia, the so-called alcoholic pseudo-tabes. On reviewing the evidence advanced by different writers Frank comes to the conclusion that such cases present no anatomically demonstrable lesion of the brain, but that the psychosis depends on such disturbances of the central organ as are usually called functional, in which with our present means of investigation no anatomical change in the brain is demonstrable. With regard to the question of Beri-Beri the author draws the generally accepted conclusion that such cases are due to infection. After a general review of the literature Frank concludes that his own case of polyneuritis without alcoholism, infection or intoxication is the sole one of the kind in literature. The psychosis was, however, characteristic throughout, and in its individual phenomena not less intense than those cases of psychoses developing in polyneuritis on an infectious or toxic basis. The etiology is sufficiently explained by the poor conditions of life to which the patient was subject for a year before the attack. Frank claims that his case shows that polyneuritis with mental disturbance may develop without one being able to allege as a cause either an infection, or even a special disease — the "cerebropathie psychica toxaemica," and that the pathological findings up to this time afford no special explanation of the psychosis in a primary pathologico-anatomical change in the brain. It results therefore that it is not simply toxaemic influences to whose influence on the peripheral nervous system polyneuritis owes its origin, and that in his case any such source, as well as epilepsy, senility and trauma must be excluded, and the only source to be sought is in the poor manner of living, which together with the small and minute injuries to the peripheral nerves is sufficient to call out the disease.

On the Psychical Disorders of Multiple Neuritis. JAMES ROSS. Journal of Mental Science, April, 1890.

Except in a few idiopathic cases multiple neuritis is due to the action of some poison,—diphtheria, septicemia, typhoid and other fevers, syphilis and tubercle; vegetable poisons like morphia; diffusible stimulants,—alcohol, bi-sulphide of carbon, di-nitro benzole, and the fumes of naphtha and other agents used in special manufactures; endogenous poisons, like those generated in rheumatism, gout and diabetes; metallic poisons, lead, phosphorous, arsenic and mercury. Multiple neuritis also accompanies many diseases like cancer, Addison's disease, exothalmic goitre, chorea, chlorosis, hæmoglobinuria, pernicious anæmia, and other diseases attended by great impoverishment of the blood. Some degree of neuritis also probably follows after severe shocks to the nervous system from injuries or moral causes. Whatever the cause of this form of neuritis it is likely to be attended by psychical disorders which have in all cases a certain family likeness; the best marked examples are in the poisoning by morphia, alcohol and other diffusible stimulants.

Ross divides the psychical disorders of multiple neuritis into four

stages: First, a premonitory stage, in which the special senses and the imaginative faculties are likely to be exalted; second, a stage of depression or melancholia; third, a transition to mania or melancholia with excitement, or of convulsions, passing on to, fourth, a final stage of dementia.

In the stage of exaltation the patient often suffers from faint hallucinations. A patient with glycosuria on closing his eyes saw all sorts of figures passing before him, such as soldiers and policemen in threatening attitudes; heard music on several occasions. In a case of alcoholic paralysis in a man of 21 when he closed his eyes a bright cloud shone before him and in the midst of it appeared faces which he spontaneously compared to photographs. In this stage there is unreasoning irritability of temper and suspicious disposition. A case illustrative of the melancholic stage was characterized by gloom, sleeplessness, mental agitation, restlessness, vivid but corrigible hallucinations in full light, and in this stage alcoholic cases find a necessity of taking stimulants for taking stimulants on going to bed. When this stage is reached the mind is apt to be chased by a tumultuous tempest of conflicting thoughts and passions which altogether prevent sleep. Ross thinks acute delirium comes on very readily when such melancholic cases begin to indulge in drink; others develop excitement or mania; while a third group manifests certain incapacities for business and are rendered unfitted for attending to their social duties. Such patients become shy and retiring, and cease to mingle in society. This timidity is seen in females who give way to secret drinking, early cease to attend to social duties, refrain from visiting, and their friends find them indisposed. As the disorder increases they become distrustful and suspicious of nearest friends, often accuse their neighbors of circulating scandals about them, or of overt acts of insult. Patients in this stage suffer from dizziness, a feeling of insecurity in walking, and a peculiar disarrangement in their perception of the space relations of surrounding objects, which may be regarded as a hallucination of the muscular sense. Ross quotes De Quincy with regard to this peculiar prolongation of the sense of time and space. In the melancholic stage the patient often suffers from remorse for some past act, often foolish, is timid and filled with thoughts prompting him to commit evil actions. These thoughts often take an erotic turn while at other times they assume the form of suicidal impulses. For the third or maniacal stage Ross refers to Bevan Lewis's text-book. In this stage there are visual hallucinations, vivid and incorrigible, burglars, detectives, men in collusion with their wives, etc. Aural hallucinations now assume the form of distinct voices uttering blasphemous oaths and curses, or are voices of ill-disposed persons intriguing against the patient, or they become commands from heaven or threats from the spirits of darkness. The delusions connected with the lightning like pains and other sensory disorders which the patient suffers are endless.

The last stage of alcoholic insanity is alcoholic dementia.

Ross's description agrees with that of Korsakoff as regards patients stating that they have been out walking, etc., when they have not left their bed.

Toxic Insanity Especially in Relation to Chronic Alcoholism. S. A. GILL. Medical Times and Circular, May 21, 1890.

Gill defines toxic insanity as caused by the presence in the circulating blood of such poisons as alcohol, opium, chloral, uric acid, lead, and the like. Discusses only alcohol in its remote effect on the nervous system. Divides alcoholic insanity into acute and chronic. The former is mania à potu, melancholia à potu, and delirium tremens. Does not discuss these, but simply calls to mind whether the symptoms they present are

found in chronic alcoholism or chronic delirium tremens, as Maudsley calls it. The symptoms are slow and gradual in their development, yet are preceded by the same premonitory signs. It is popularly thought that whenever the mind gives way from alcoholic excess that delirium tremens must result; this is erroneous as there are hundreds of alcoholic subjects who never have delirium tremens, yet slowly and surely develop nervous symptoms that bring them within the walls of an asylum. No general description of the mental condition in such cases is given; a case of chronic alcoholism is described and the pathology of this disease is given.